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OCT 26 1906

SCIENTIFIC AMERICAN SUPPLEMENT. No. 1608

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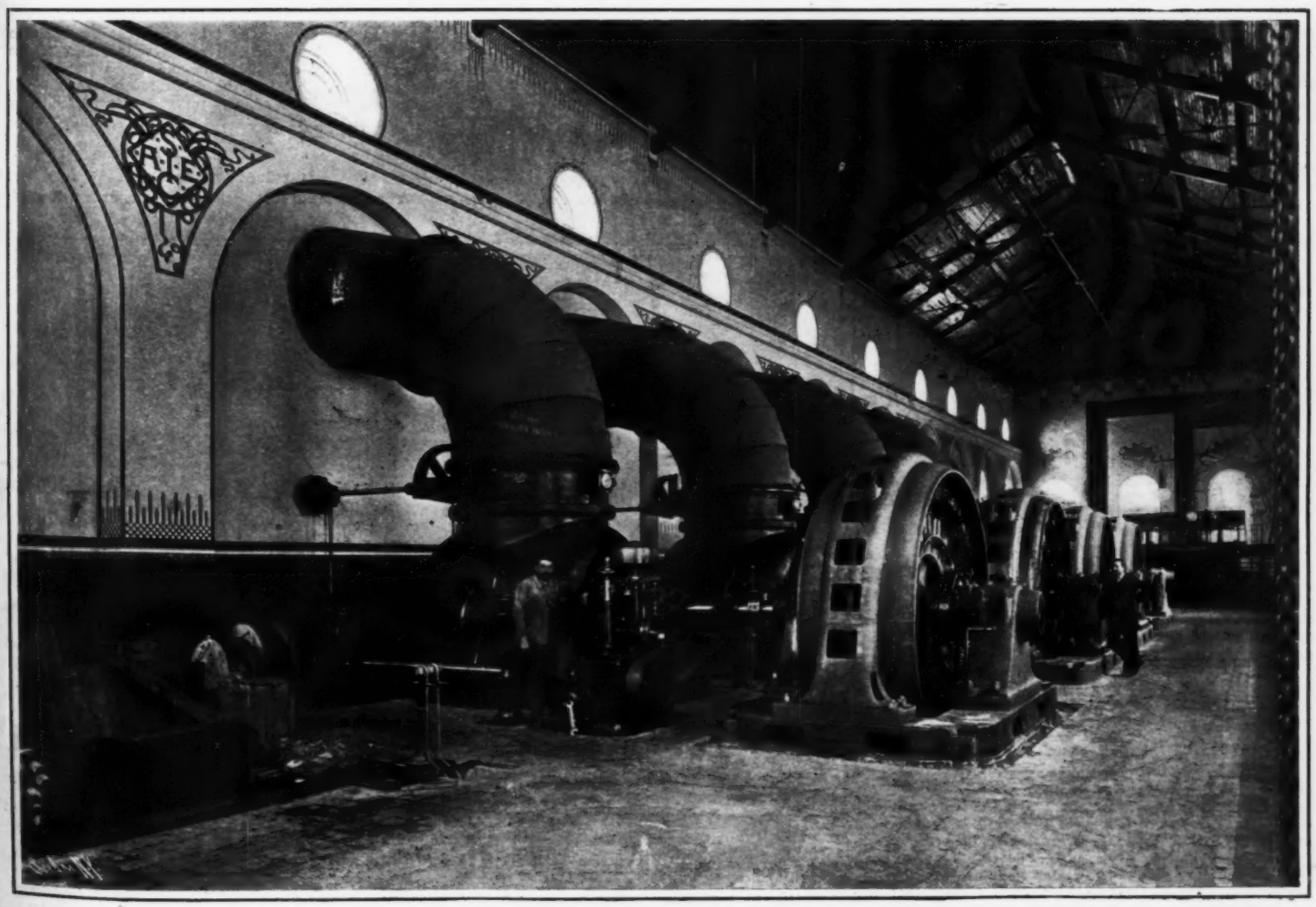
Scientific American, established 1845.
Scientific American Supplement, Vol. LXII., No. 1608. NEW YORK, OCTOBER 27, 1906. Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

VIEW OF THE GATES THROUGH WHICH THE WATER PASSES TO THE TURBINES.



A GENERAL VIEW OF THE INTERIOR.

BOFFALORA-TICINO HYDRO-ELECTRIC POWER PLANT.

BOFFALORA-TICINO HYDRO-ELECTRIC POWER PLANT.*

By Dr. ALFRED GRADENWITZ.

IN order to utilize the water of the Ticino River an extensive hydro-electric power plant has been recently installed at Boffalora-Ticino, supplying electrical energy to the cities of Milan, Pavia, Novara, and Vigevano.

THE SWITCHBOARD.

This power plant owned by the Società d'Imprese Elettriche Conti, with an output of 25 cubic meters per second and a head of 18.60 meters, embodies the latest improvements as regards the hydraulical, mechanical, and electrical parts.

Part of the 25 cubic meters per second utilized in the plant is diverted immediately from the Ticino River (20 cubic meters) by means of an intake situated beneath the Boffalora Bridge and partly (5 cubic meters) from the Naviglio Sforzesco, which is likewise a diversion from the Ticino farther ahead. The immediate intake has been installed on the right bank of the river, as the course of the latter in the neighborhood of the diversion tends to approach this bank; while other circumstances also warrant a more satisfactory supply on the right bank.

The output of the Ticino at the Boffalora Bridge, while in some exceptional cases falling down to 8 cubic meters, as a rule is never below 11 cubic meters, while an average of 20 cubic meters may be realized on about 320 days in the year. The diversion was effected without any stationary dam, by means of three elevations, traversing the river, which are arranged stepwise between the banks and two islands in the river.

The intake construction, which is about 18.4 meters in length, normally allows the water a speed of passage of 2 meters per second. The small amounts of sand that the water may carry along into the supply channel may be discharged through a sluice-gate of 20 cubic meters capacity, situated at 3.54 kilometers and immediately emptying into the Ticino River.

The supply channel starting from the Boffalora Bridge is mainly built with concrete and cement; and after a run of some 1,700 meters, it terminates in the Naviglio Sforzesco, raising the 15 cubic meters water of the latter to 35 cubic meters. For a distance of about 14 kilometers there is a single channel, after which a division is operated by means of the two slide-gate constructions, the Sforzesco channel continuing with an output of only 10 cubic meters water, while the industrial channel having an output of 25 cubic meters leads to the collecting basin, whence the penstocks start toward the power station. This basin is about 1.7 kilometers distant from the branching point of the two channels. The normal cross-section of the supply channel is trapezoidal throughout, with an inclination of 45 deg., while slopes of 1.5 only obtain on some short sections, when the base, in order to maintain the flow constant, is enlarged in proportion.

From the collecting basin the water is led to the turbines through metal penstocks. Satisfactory local conditions have greatly facilitated the arrangement of the hydraulic plant, and warrant its stability. The forebay is entirely inclosed in a natural basin. There are seven penstocks, two of which are intended for the exciter sets and five for the generators. The available head is 18.6 meters. The spillway is only 400 meters in length, and has an inclination of 0.72 per cent and a width at the bottom of 24.0 meters. It terminates in the Ticino River above the bridge referred to.

The Power Station.—The engine house, 63 meters in length and 12 meters in width, contains both the generators and transformers, while the switching plant is installed at about two-thirds of its length. The arrangement has been so chosen as to enable a single crane to cover both parts of the hall.

The turbines, constructed by Messrs. Riva & Monneret, are seven in number, five of which are intended for the operation of the alternators and two for the exciter machines, the former having an output of 1,400 horse-power each with a speed of 315 revolutions per minute, while the remaining two of 150 horse-power each make 750 revolutions per minute. The electrical machinery has been constructed by the Unione Elettrotecnica Italiana. The alternators directly coupled to each of the five turbines are three-phase machines, giving a pressure of 2,700 volts at 42 periods. This frequency has been chosen in order to enable the plant to work in parallel with the Paderno plant.

The two small turbines directly operate two dynamos, which serve for the excitation of the alternators, one being in reserve.

The current generated by the five alternators is raised from 2,700 volts to 25,000 volts by single-phase transformer sets, one of which serves as a reserve, and each of which is constituted by two single-phase transformers of 535 KVA capacity each, with forced ventilation. There is a ventilator driven by a special motor for each three transformers.

Conductors for Transmission of Electrical Energy.—From the power station the current is led by means of eighteen 25,000-volt lines to the several towns in which it is utilized. A double wire, 30 kilometers in length, transmits the energy to Milan, terminating at Porta Vigentina. It is mounted on iron poles which, like those applied in connection with the Brembo plant, are elastic in the longitudinal direction of the line. The portion running alongside the Ticino for a distance of 310 meters is especially noteworthy. It consists of phosphor-bronze cables supported by pillars 14 meters in height, each of which without any anchoring carries as much as 17 tons. Another single line 30 kilometers in length, mounted on poles susceptible of carrying another line, leads to Novara. The iron poles this line is mounted on are rigid; the line itself is the most tortuous transmission line existing in Italy. Another line 30 kilometers in length of similar arrangement leads to Pavia, while a fourth single line of only 15 kilometers' length runs as far as Vigevano and Mortara. From the Milan transmission line the energy required for Corsico is derived, while from the Novara line a derivation intended for supplementing the Cerano-Trecate power plant is branched off. All these lines are provided with Perego telephone outfits.

THE ALTERNATORS.

BOFFALORA-TICINO HYDRO-ELECTRIC POWER PLANT.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

[Continued from SUPPLEMENT No. 1607, page 25755.]

DIGEST OF THE REGULATIONS AND INSTRUCTIONS CONCERNING THE DENATURATION OF ALCOHOL.*

SPECIAL DENATURANTS.

As the agents adapted to and adopted for use in complete denaturation render the alcohol denatured unfit for use in many industries in which ethyl alcohol, withdrawn free of tax, can be profitably employed, therefore, in order to give full scope to the operation of the law, special denaturants will be authorized when absolutely necessary. Yet the strictest surveillance must be exercised in the handling of alcohol incompletely or specially denatured. The Commissioner of Internal Revenue will consider any formula for special denaturation that may be submitted by any manufacturer in any art or industry and will determine (1) whether or not the manufacture in which it is proposed to use the alcohol belongs to a class in which tax-free alcohol withdrawn under the provisions of this act can be used, (2) whether or not it is practicable to permit the use of the proposed denaturant and at the same time properly safeguard the revenue. But one special denaturant will be authorized for the same class of industries, unless it shall be shown that there is good reason for additional special denaturants. The Commissioner will announce from time to time the formulas of denaturants that will be permitted in the several classes of industries in which tax-free alcohol can be used. (Sec. 79.)

Upon the approval of the bond, the collector shall issue a permit to the manufacturer, numbered serially.

Manufacturer to Give Notice of Denaturer from whom Alcohol is Secured.

Manufacturers who have given bond and received a permit and are thereafter authorized to use alcohol denatured with special denaturants may secure from any distiller who is a denaturer of alcohol the alcohol to be used in their business. (Sec. 91.)

The manufacturer must give notice to the collector of the district in which his establishment is located in duplicate if the manufacturing establishment and the denaturing bonded warehouse at which the alcohol is denatured are in the same collection district, and in triplicate if they are in different districts.

Upon receipt of this notice the collector retains one copy in his office. The other copy he forwards to the Commissioner of Internal Revenue, and, if the manufacturing establishment and the warehouse at which the alcohol is to be denatured are in different districts, the third copy is forwarded to the collector of the district in which the denaturing bonded warehouse is located. (Sec. 91.)

Regulations Prescribed in Case of Completely Denatured Alcohol to Apply.

The regulations prescribing the manner in which alcohol is to be withdrawn from warehouse, transferred

* In this digest only those portions of the regulations which are of interest to the distiller and the proprietors of restoring and redenaturing plants have been retained; the rules to be observed by government officers in keeping records, etc., have been omitted as well as the regulations controlling the use of denatured alcohol in manufacturing industries.

to denaturing bonded warehouse and dumped, the manner in which the denaturants are to be brought upon the premises, stored and tested in the case of completely denatured alcohol, apply in case of specially denatured alcohol; likewise the regulations prescribing the manner in which completely denatured alcohol is to be drawn off, after being denatured, gaged, marked, etc., apply in case of specially denatured alcohol. In the case of specially denatured alcohol a special mark must be put upon the stamp-head. (Sec. 93.)

Special and Complete Denaturants Not to be Mixed.

In no case is completely denatured alcohol to be mixed with specially denatured alcohol and special denaturants are to be kept completely separate from denaturants used in complete denaturation. The officer in charge of the warehouse must be careful to see that denaturing material tanks are empty before any special or complete denaturing agents are dumped. Likewise he must be careful to see that the mixing tanks are empty before any dumps, either for special or complete denaturation, are made.

Specially Denatured Alcohol to be at Once Put in Transit.

As soon as specially denatured alcohol is gaged and the packages are properly marked and stamped, it must be removed from the denaturing bonded warehouse and put in transit to the manufacturer for whom it was denatured, and under no circumstances must any other disposition be made of any part of it. (Sec. 95.)

Reports at Warehouse, etc.

Reports, records, etc., relating to the alcohol after it has been denatured, and to be made and kept by the officer and the distiller must, in the case of specially denatured alcohol, contain columns and spaces for showing and must show the name and address and number of the manufacturer to whom the alcohol was sold, and certain additional reports must be made by the officer and the distiller. (Sec. 96.)

Notice of Shipment of Specially Denatured Alcohol.

The distiller must prepare and forward a report giving notice of shipment of specially denatured alcohol.

ALCOHOL RECOVERED, RESTORED, AND REDENATURED.

Alcohol to be Restored on Premises Where Used or in a Restoring Plant.

The work of recovering alcohol and restoring it to conditions suitable for reuse in manufacturing processes must be done on the premises on which the alcohol was originally used or at a duly authorized restoring plant, and it must be reused in the same manufacturing establishment in which it was originally used (except as specially provided).

Still May be Used.

If in restoring alcohol to a condition suitable for reuse a still is necessary, the manufacturer may set up on his premises such still and any other apparatus that may be necessary for use in connection with or independent of the still in the work of recovering such alcohol. The still must be registered in the same manner in which the law and regulations require that all stills set up be registered. It can not be used for any other purpose than to recover by redistilling alcohol that has been withdrawn from bond free of tax for denaturing purposes, denatured, and then used by the manufacturer. (Sec. 113.)

Application to be Used.

A manufacturer desiring to recover and reuse such alcohol must in his application for permit to use denatured alcohol in his business, in addition to the statements required to be made in said application, state fully the manner in which he intends to recover alcohol, the condition as to proof, purity, etc., of the alcohol when it is recovered, the percentage of alcohol used in said business which he proposes to recover, and the estimated quantity in proof gallons of alcohol he expects to recover during the year. If it is necessary before redenaturing the alcohol to redistill or otherwise treat it in order to restore it to a condition suitable as to proof and purity for use in the particular manufacture for which it is intended, the process must be explained, and if a still is used the capacity of the still must be set out in full and the other apparatus used in connection with the still must be described. (Sec. 114.)

Alcohol to be Stored in Storeroom as Recovered.

The manufacturer must draw off the alcohol as it is recovered into packages and must immediately store it in exactly the same condition as it is when recovered in the storeroom for denatured alcohol, and it shall thereafter be in charge of the custodian of said warehouse. Alcohol recovered at such establishment and placed in the warehouse for denatured alcohol will not be redistilled or otherwise treated except in the presence of the proper officer. (Sec. 116.)

Still Used for Recovering Alcohol Only, etc.

The still employed in redistillation must not be used for any purpose except to redistill alcohol for redenaturation, and it must not be used except in the presence of the proper officer. When the still is not being used the furnace door or cocks controlling the steam connections will be securely locked and the collector will keep the keys to said locks in his possession. (Sec. 117.)

Application to Have Alcohol Restored and Redenatured.

At such intervals as the necessities of the business may demand, and when the manufacturer has a sufficient quantity of recovered alcohol on hand to justify the sending of an officer to his place of business, he may make application to the collector of the district for an officer to be detailed to supervise the work of redistilling or otherwise treating the recovered alcohol and the redenaturing of it. (Sec. 118.)

Collector to Detail Officer to Visit Manufacturing Plant.

Upon receipt of the manufacturer's notice the collector will detail an officer to proceed to the manufacturing premises in question and supervise the work of restoring to suitable condition and redenaturing the alcohol mentioned in the notice.

Officer to Visit Manufacturing Establishment.

Upon receipt of these instructions the officer will proceed at once to the manufacturing establishment, and will supervise the work of restoring and redenaturing the alcohol in accordance with the regulations. (Sec. 120.)

The agents to be used in redenaturing must be brought into the storeroom and must be inspected by the officer immediately upon his arrival there. He must take samples of each denaturant and forward them, properly marked and labeled, to the nearest laboratory. If the denaturants are in two or more packages he must secure an equal part from each package so that the sample will be a representative one.

The packages or tanks containing the denaturants must be sealed and must remain sealed until the officer receives the report upon the samples sent. If the report is favorable to the samples, the officer in charge of the storeroom may, after the receipt of the report, permit the denaturing agents to be used in accordance with the general or special specifications, as the case may be, in redenaturing alcohol at said storeroom. (Sec. 121.)

If the report is unfavorable the proposed denaturants must at once be removed from the storeroom by the manufacturer. While the officer is at the manufacturing establishment supervising the work of restoring and redenaturing the alcohol, the storeroom will be in his custody and he must carry the key to it.

Restoring, Redenaturing, and Gaging the Alcohol.

The process of restoring the alcohol to a condition suitable for use is carried on in the presence and under the supervision of the officer. If in the process of restoring the alcohol to a condition suitable for reuse it is necessary to remove it from the storeroom, it will be returned to the storeroom as rapidly as it is restored and drawn off into suitable packages. The officer will, in having the packages filled with the restored alcohol, leave a wantage equal in volume to the denaturants to be added. He will ascertain by weight the wine and proof gallons in each package before any denaturant has been added. He will then cause the denaturants to be added to the package and will gage, mark, stamp, and brand the package of redenatured alcohol.

The same kind of packages and stamps prescribed by these regulations for alcohol denatured at denaturing bonded warehouses will be used for alcohol redenatured at storerooms for denatured alcohol. Packages of redenatured alcohol shall be numbered serially, beginning with number one, at each storeroom.

Packages to be Marked, Stamped, and Branded.

The officer must mark and stamp the package when he gages it.

Manufacturer to Keep Record.

The manufacturer must keep a record in which he shall enter daily in proper spaces and columns the quantity in wine and proof gallons of alcohol recovered by him and placed in storeroom, the quantity of denaturants placed in said storeroom for redenaturing purposes, and the quantity of alcohol, in wine and proof gallons, restored to a condition suitable for use, and the quantity of each denaturant used. He will also enter in said record daily the quantity of alcohol redenatured in his storeroom, the serial numbers of the packages, the serial numbers of the denatured alcohol stamps, and the wine and proof gallons of the redenatured alcohol. (Sec. 127.)

He must prepare a transcript of this record at the end of the month, and before the 10th day of the following month he must swear to it and forward it to the collector of internal revenue. The affidavits to this report must be made by the custodian of the storeroom and the manager of the business.

The manufacturer must also enter on his record of denatured alcohol received and disposed of the packages of alcohol redenatured at the storeroom. The alcohol must be treated in the same manner on the record as it was when received originally.

In the summary on said record the quantity of alcohol received from re-denaturation and re-used must be shown in items separate from the denatured alcohol coming into the stock originally from dealers and denaturers.

Collector to Keep Account with Manufacturer of Alcohol Restored.

The collector must keep an account with each manufacturer who recovers, restores, and re-denatures alcohol. This record must be made from the reports of the chemist, officer in charge of the storeroom, and manufacturer. It must show the quantity of alcohol recovered and deposited in storeroom each day, the quantity restored to a condition suitable for reuse, the quantity and kind of denaturants used in denaturing said alcohol, the name of the officer supervising the restoring of and redenaturing of said alcohol, the number of packages and the serial number of same, and the quantity in wine and proof gallons of alcohol redenatured, gaged, and delivered to the manufacturer for reuse. (Sec. 130.)

Alcohol Not to be Redenatured Unless Necessary.

Manufacturers who recover alcohol will not be required to have the alcohol redenatured if it retains a sufficient quantity of the original denaturants to prevent its use as a beverage. If necessary, this may be determined by the chemical examination of samples taken for this purpose and forwarded to the nearest laboratory. If it is not necessary to redenature the alcohol the manufacturer must deposit it in his storeroom in suitable packages and make application to the collector of internal revenue to have it regaged and restamped. The collector will detail an officer to visit the storeroom and regage and restamp the alcohol. When it has been regaged and restamped the alcohol will be taken up on proper records by the officer and the manufacturer, and will appear on the monthly reports in the same manner as though it had been redenatured. The officer making the regage will make a report in the same manner as is required when alcohol is redenatured on the manufacturer's premises, except that the report will not show that the goods are redenatured. (Sec. 131.)

(To be continued.)

QUEER FOODS USED IN VARIOUS COUNTRIES.*

THE list of queer foods eaten in different parts of the world reminds us very forcibly that one man's meat is another man's poison. The intercourse between nations leads very often to the adoption by one of another's favorite dish. Thus snails, always so popular in France, no longer offend the American palate, but, indeed, are relished highly and eaten by many persons in this country. Why they should be rejected by the man who likes oysters is truly a mystery.

The Medical Register names some of the articles of diet which are popular among various people.

In Canton, rats sell for fifty cents a dozen, and dogs' hind-quarters command a higher price than lamb or mutton. Fancy eating birds' nests worth thirty dollars a pound! This is what a mandarin revels in.

In the West Indies baked snake is a common dish, where the reptiles abound, and it is a good way of getting rid of them. But when it comes to frying palm-worms in fat, one would think the stomach would rebel. It is not so, however, though, by a strange inconsistency, stewed rabbit is looked upon with disgust.

On the Pacific coast the Digger Indians eat dried locusts, and in the Argentine Republic skunk flesh is a 'ainty.

Our own favorite bivalve, the oyster, is very disgusting to a Turk, while the devil-fish, eaten in Corsica, is equally so to us.

We cannot understand, either, how the inhabitants of the West Indies and the Pacific coast can eat lizards' eggs with a relish; still less, how the eggs of the turtle and alligator can become a favorite article of diet.

The Brazilians eat ants, probably to get rid of them, for they literally infest the country, and are of an enormous size.

Parrots are eaten in Mexico, while roasted spiders are considered a delicacy in the New Caledonias. Silk-worms are found delicious by the Chinese. Caterpillars are to the African like reed-birds on toast, and bees are eaten regularly by the Singalese.

Geophagy, or the habit of earth-eating, is mentioned in the Medical News as bein very widespread. Stone butter is a fine clay used upon bread in place of butter in many parts of Germany. Earth is baked in bread in the northern part of Sweden and on the peninsula of Kola. It is also sold in the open market in Sardia and in parts of Italy, while the Persians use it in the manufacture of sweetmeats.

In Nubia it is used as a medicine and to many primitive tribes its use has also a religious meaning. The habit is general over almost all of India, and the gray or drab-colored shale, which is the favorite in northern India, and which is excavated mostly at Meth in Bikanir, is exported to the Punjab at the rate of two thousand camel loads a year.

In different districts different varieties of clay are eaten, but if the natives have at one time a taste for a special kind of mud, as the habit increases the depraved appetite soon becomes satisfied with bricks and broken pots. White ant soil, with the nests and ants themselves, is a great delicacy.

The reasons given for indulging in the habit are classified under the following heads: 1. A peculiar fascinating odor and taste in the clay, rendering it a delicacy. 2. An unnatural craving due to disease. 3. To satisfy hunger. 4. Force of example. 5. Supposed medicinal virtues.

A university graduate confessed to a friend that the bland earthy odor was a great temptation to him, and the thought of it made his mouth water.

Probably the most remarkable of all appetites is the alleged Mexican taste for dynamite. The story has not been verified, but it was published by a reputable New York daily newspaper which is not usually classed with "yellow" publications. The taste is confined to a certain Mexican locality where the people break off the explosive, roll it into a pill, dissolve it in a glass of mescal and drink the liquor, the result being a delightful and vision-engendering intoxication.

* The Scrap Book.

RESISTANCE OF BUILDING STONES TO FROST.

Atmospheric variations exercise so prejudicial an effect upon certain building stones that the opening of a new quarry is a matter of considerable importance, for architects and engineers do not adopt materials from fresh sources without being fully satisfied as to their reliability. The prudence of this course is further justified by the fact that cases have occurred where builders have been compelled to suspend operations because they have been insufficiently informed as to the resistance to frost of the stone employed. Therefore, it must be agreed that the resistance of structural materials to frost is a question of primary importance.

During a long period the Brard process was the only means by which account could be taken of the characteristic of stone to which attention is here directed. Although not enabling the problem to be solved in a direct and absolute manner, it furnished approximate results that were formerly accepted as sufficiently satisfactory.

This process was conducted by immersing a fragment of stone with sharp edges, or preferably a cube measuring a few centimeters across, in a cold saturated solution of sodium sulphate. The solution was then boiled for thirty minutes, after which the stone was removed and exposed for eight to ten days in a chamber, where a moderate and constant temperature was maintained. At the end of this period the specimen was examined. If it remained intact, its resistance to frost was considered to be satisfactory. On the other hand, if the edges had lost their sharpness, showing splinters that appeared to be on the point of separation and that could be carried away by a jet of water from a wash-bottle, it was regarded as liable to injury by frost.

Some modifications were made in this mode of operation by MM. Vicat, Héricart de Thury, and Husson, who attempted to render the details of execution more methodical. These scientists recommended that observations should be made at the end of pre-determined periods, and that the particles carried away by washing after each period should be weighed for purposes of comparison.

In spite of these modifications the process still presented the grave defect of indicating materials as liable to injury by frost which were not so affected, the fact being that much of the deterioration observed was caused by unduly protracted treatment.

M. Braun then attacked the problem in a different manner. He proposed to characterize as liable to injury by frost all stones whose resistance to tension is less than the expansive force of water at the moment of congelation. This idea was certainly rational, since it is precisely the increased volume of water in passing from the liquid to the solid state that causes the disintegration of stone under the influence of frost. But the absence of exact experimental methods and the inadequacy of the results obtained caused M. Braun to abandon his process.

In the present day the resistance of stone to frost is determined by laboratory tests based upon successive and rapid variations of temperature.

The specimen of stone selected for examination is cut in the form of a 7-centimeter cube, which is submerged in a vessel containing water. The vessel is placed under the receiver of an air-pump, air being exhausted until a partial vacuum of 10 inches is obtained. The quantity of water absorbed is naturally governed by the porosity of the material. If the stone is not to be employed under water it is sufficient to accept the natural absorption of the cube after immersion in water for twenty-four hours. After saturation the cube is introduced into an apparatus containing a freezing mixture capable of maintaining during several hours the temperature of from —20 deg. to —15 deg. C. After being exposed for four hours to the temperature of, say —15 deg. C., the cube is removed from the apparatus and immersed in distilled water, or, in default, in drinking water, of which the temperature is +15 deg. C. The specimen is then examined. In cases where distilled water is employed for washing, the water is collected and examined for soluble salts.

Sometimes the tests are completed by determining the compressive strength of the stone under examination, the specimens being dried after twenty-five successive freezings and thawings, and by comparison of the resistance with that of the original stone tested in the dry state and after the absorption of water to the point of saturation.—Prof. J. Malette in The Builder.

It is a well established fact that it is not safe to form a judgment of a water from the consideration of any single nitrogen factor, and that unpolluted surface waters are known where the nitrogen, as albuminoid ammonia, is much larger than in certain waters known to be polluted, and the same can also be said of nitrogen as free ammonia and the nitrogen as nitrites and nitrates, and yet something can be learned from the consideration of each of these factors. Nitrogen as albuminoid ammonia in a water analysis represents the nitrogenous matter which has not undergone decomposition, and it is found that in unpolluted waters this amount varies greatly, some waters giving almost no nitrogen in the above form, others as much as one milligramme per liter. If, however, the nitrogenous substances are of vegetable origin the water is usually highly colored, and consequently a colorless water containing that amount of nitrogenous matter represented by 0.25 milligramme of nitrogen as albuminoid ammonia per liter is looked upon with suspicion.

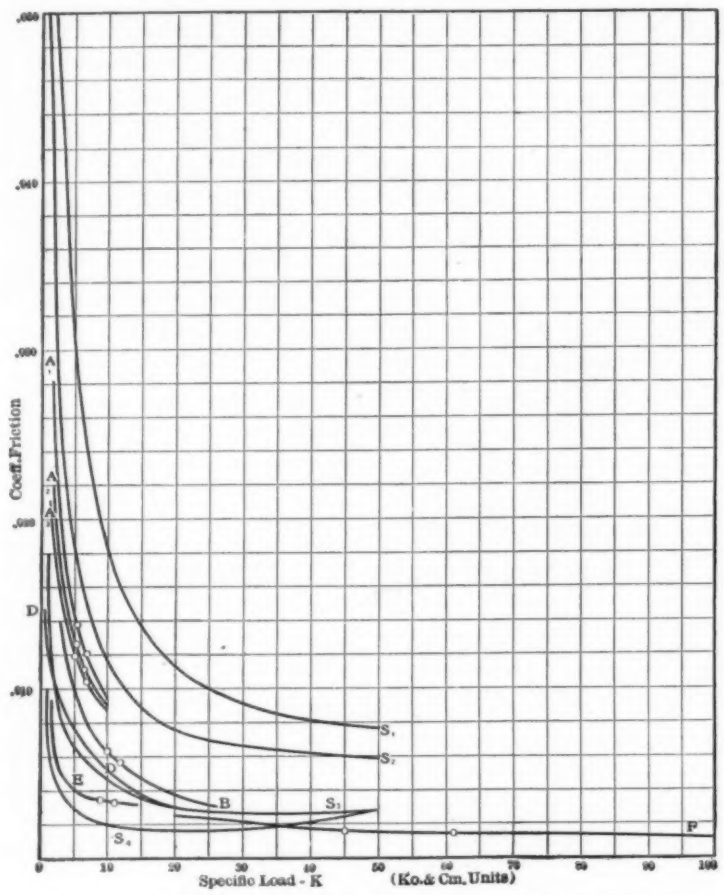
BALL AND ROLLER BEARINGS.*

By Henry Hess.

My contribution to the general discussion of bearings will be confined to a necessarily rather brief and cursory review of ball and roller bearings, and a slightly more detailed reference to ball bearings of a type with whose development and operation I am personally familiar.

Both ball and roller bearings are of hoary origin. The roller used under a block of stone by the ancient Egyptians and in exactly the same way under the skids of a crate containing the latest product of the modern machine shop show familiarly the advantage of the substitution of rolling for sliding friction.

The early recognition of this advantage led naturally to many attempts at the employment of rolling elements in the journals of machines. Until relatively recent days such attempts have been chiefly failures—interesting, but failures nevertheless. The causes were simply imperfections in the shape of the rolling elements and their supporting surfaces, resulting in the loads being actually imposed on insufficient areas, though, theoretically, greater ones were provided.



The specific load is the load per unit of the carrying element; for plain bearings such element is the projected journal area or : $K = LD$.

For roller bearings the projected area of the carrying rollers (one-fifth of the rollers only is considered as carrying) is $K = \frac{Z}{5} LD$.

For ball bearings the squared ball diameter of all carrying balls is taken (one-fifth of the balls only are taken as really carrying) $K = \frac{Z}{5} D^2$.

Curves "S" are for a babbitted journal — S_1 at 1100 R. P. M., S_2 at 380, S_3 at 64, S_4 at 12.

Curves "A" are for rollers in a bronze cage circumferentially fitting and supporting each roller throughout its length. A sleeve on the shaft and a liner in the box carry the rolls. Hard and soft rollers were tested. A_1 at 1100 R. P. M., A_2 at 285, A_3 at 190.

Curves "B" are for hollow rollers on loosely fitted pins that connect the end cages. No liners are used on the shaft or in the box. R. P. M. from 190 to 760.

Curves "E" are for flexible spiral rollers; the rollers are loose and are alined by three longitudinal bars connecting the end cages. No liners for shaft or box are employed. 56 to 1100 R. P. M.

Curves "F" are for a ball bearing of the two point curved ball race type at 65 to 1150 R. P. M.

The range of permissible specific loads, as indicated by the appearance of the bearing after long continued runs, is shown by small circles on the curves.

Fig. 1.—TESTS OF PLAIN, ROLLER, AND BALL BEARINGS.

Then, too, the laws for securing true rolling and eliminating all slidings have been formulated only relatively recently, so that at this day it is not uncommon to find thrust bearings with cylindrical rollers, that necessarily can have pure rolling at only a single girdle in their length while all other parts must slide, since only balls of cones whose apices lie in the center of revolution can roll truly.

The bicycle is responsible for the widespread realization of the possibilities of the saving of work by ball bearings; without these it probably would never have had the vogue it acquired; the rider who remembers the difference in freshness at the end of a half day's tour on a wheel fitted with cone bearings and one fitted with ball bearings can bear eloquent witness. Simple as is the design of a ball bearing of correct action, yet but few gave proof of anything but mistaken ingenuity. The saving element in the bicycle was the light load. The hopes cherished and translated into practice for more ambitious mechanisms soon resulted in failure. This was attributed to insufficient bearing surface. Further development was along two lines: One body of constructors fell back to rollers, with the idea that a roller had line and therefore more support than a ball with its theoretical mere point; others multiplied the number of balls.

GERMAN EXPERIMENTS ON BEARINGS.

Some years ago Prof. Stribeck, the able head of the Technical Laboratories at Neu-Babelsberg, near Berlin, undertook for one of Germany's leading industrial establishments a thorough investigation of the entire subject of the relation of sliding, roller, and ball bearings. The maximum loads under which the temperature remained constant were determined. There was also considered the time that a bearing had to be run under a given load until such constant temperature was attained.

The results are given in Fig. 1 in the relation of the coefficient of friction (referred to the shaft diameter) to the specific loads. For sliding bearings the specific load is the pressure in kilogrammes per square centimeter of projected journal area; for roller bearings one-fifth of the number of rollers times the length and diameter of the rollers is considered as the equivalent of the projected journal area; for ball bearings one-fifth of the number of balls times the square of the ball diameter is considered as such equivalent. Within the limits of numbers of balls and rollers in an ordinary journal one-fifth of such number may be considered as practically sustaining the load, though naturally not equally. For roller and ball bearings angular velocity has not much influence within quite wide limits; wider for balls than for rollers; note the revolutions-per-minute figures of the curves.

Noticeable is the very low coefficient of friction of the roller—and more especially of the ball bearing. A further marked characteristic that these tests developed was the value of the coefficient of friction at rest; with roller bearings the latter was far less than with plain bearings, and for the ball bearings the friction of rest and motion was found to be identically low; this is a very important quality in all machines that must be frequently started and stopped, as suburban and urban train and car service.

Stribeck concludes that for continuous service with roller bearing K may lie between 6 and 11 kilogrammes.

For lineshafts employing soft rollers the journal length works out but slightly less than the usual plain

* Abstracted from the discussion on Bearings at the New York meeting of the American Society of Mechanical Engineers.

box length; *K* should lie well toward the lower limit. For hardened rollers on hard surfaces *K* may lie toward the higher limit. It is important that the rollers should be parallel to the shaft when under load. Tests of various cage constructions and of free rollers have shown that this is attained most nearly when the rollers are not tied together but are left free to adjust themselves; lack of truth will cause a slewing of the rollers as they pass under the load; as they pass out to the free side of the journal they can again straighten out unless confined in rigid relationship to those still under load.

At first glance the relatively high carrying capacity and low friction of the ball bearing as compared with the rollers seems strange. The explanation is not far to seek. For pure rolling there would be no difference between ball and roller; but pure rolling is a theoretical possibility merely, requiring for its realization absolutely true shapes initially, and inelastic materials that will not change shape under load. To produce a series of rollers that are truly cylindrical alike as to diameters and also a cylindrical shaft for them to roll on, and a truly cylindrical box to roll in, within the requisite small limits of error is difficult and commercially not realizable with existing shop facilities. More serious still is the fact that under heavy loads even such accuracy as may be had is largely defeated by the deflections of the machine framing. The familiar tendency of rollers to skew is the result of such lack of truth or deflections. It follows that the theoretical line of contact of the roller does not exist in fact, but is limited to but a short portion of the roll length.

Difficult as the production of a true ball is under ordinary shop conditions, specialists in the manufacture of this article can deliver balls at relatively small cost that are true spheres to within less than one-ten-thousandth part of an inch. This fact suggested the substitution of a large number of balls for a small series of rollers in the solution arrived at by Simonds of Fitchburg; there remained still the difficulty of the lack of truth of the shaft and box; to make up for this by selecting balls to suit successive zones was a way out, but hardly a commercially practicable one. Many constructions were devised for rocking and compensating mountings that would also take care of the difficulties introduced by deflection under load of the supporting shaft and box. Finally a German engineer, Mr. Riebe, decided that the proper thing was to employ but a single row of balls and so have a journal of no appreciable length that therefore could not cause trouble by deflection, and then to proportion the diameter and number of balls to the load to be carried. As the number of balls in a single circle was necessarily limited, and as the journal diameter could not be indefinitely increased, it became important to develop the carrying capacities as affected by the shape of the ball tracks and the nature of the materials. Tests were made of ball bearings of various shapes and relationship of contact. It was found that the frictional resistance was least for balls rolling between straight line sections, Fig. 2, of the two-point order of contact. It was further found that increasing the points of contact to three and four, Figs. 3 and 4, gave higher frictional resistance, due no doubt to the slight variation from the correct relationships of the contact points and the centers of revolution of balls or journal; the carrying capacity was not materially different for these forms. Theoretically, No. 4 should carry rather more, but the greater tendency to partial sliding, as compared with the pure rolling of No. 2, offsets this. Curving the race, Fig. 5, resulted in materially greater carrying capacity with but barely measurable increase in friction.

PROGRESS IN BALL BEARING DESIGN.

Naturally, as the carrying capacity of a bearing with curved race sections was greatest, it followed that any openings for side filling of the balls, which would break such section and therefore reduce the capacity, must be kept at the unloaded side or avoided altogether. Riebe's design, Fig. 6, was along the former lines; the ball was introduced through a cut in one race at the side; the continuity of the race was restored by a clip; but still the joint was a weakness, so that the screw-head was utilized to keep this joint at the unloaded side. Later a Mr. Conrad suggested that it would be better to have no weak point, but that both races be of uniform section throughout; better still, he also accomplished this by filling in as many balls as would fill one-half of the bearing, assembling this, distributing the balls and then inserting separators that could maintain such distribution and so lock the whole into a complete unit. The lesser number of balls were compensated for by larger sizes and by the possibility of somewhat higher loading under most conditions owing to the absence of certain interferences incidental to every ball bearing having balls in unyielding contact.

Further experiments—again carried out by Prof. Stribeck—on bearings and balls of various sizes and races of various degrees of curvature and many standard and special steel alloys, developed data for the reliable design of bearings suited to all sorts of conditions.

That these two constructors have, backed by the researches of Prof. Stribeck, been successful to the point where the most conservative need no longer shy at the employment of ball bearings under any conditions is best proven by the consideration of a few typical examples from actual practice. As the mention of firms is more or less out of place in a discussion such as this, no names appear, but it may be said that the various prints shown all represent constructions that have been actually carried out and are standard practice with firms of international reputation.

Fig. 7 is a continuous annular race; it consists of an inner race, an outer race, both provided with curved ball tracks that are uniform and unbroken around the complete circumference and of a series of balls, separated by elastic distance pieces, which latter are usually provided with felt plugs for storing up lubricant.

EXAMPLES OF BALL BEARINGS FOR HEAVY LOADS.

The first example shown, Fig. 7, is the mounting of a tubular cement mill. This is also interesting as a journal of somewhat unusual dimensions—39 inches—and will carry safely 40,000 pounds of weight in such a machine.*

In a pillar crane of a certain French type the whole load of 39,000 pounds is hung on top of the post and sustained by a ball thrust, Fig. 9, making use of 1¾-inch balls. Immediately below it a radial bearing takes the 21,000 pounds of horizontal thrust on 1⅝-inch balls.

The mounting of this paper calender roll, Fig. 10, is the first shown in which the load is taken on two rows of balls. The standard practice is to carry all the load on a single row of balls owing to the virtual impossibility of dividing it with certainty among more. Where, however, a one-sided journal can be employed, as in railway axles, calenders, etc., an equalizer is practicable. In this case, the bearing box is hung on a trunnion (dotted lines) midway between the two rows of balls. The outer races of the ball bearings are loaded on one side only and entirely free on the other. Both will therefore receive an equal part of the load; this distribution will be unaffected by spring of the frame, etc. The arrangements shown will carry a total roll load of 56,000 pounds.

Few mechanisms employ balls larger than these 3½-inch ones that serve to give ease of rotation to a 7-inch naval gun mount, Fig. 11. The steady load carrying capacity of over 90 tons is, of course, far in excess

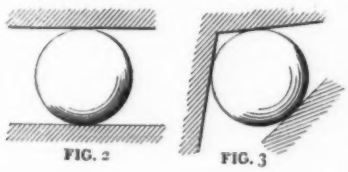


FIG. 2

FIG. 3

FIG. 4

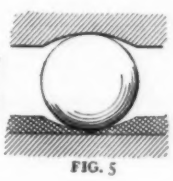


FIG. 5

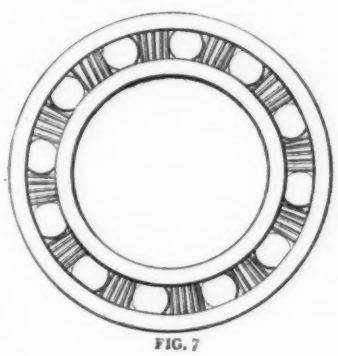


FIG. 7

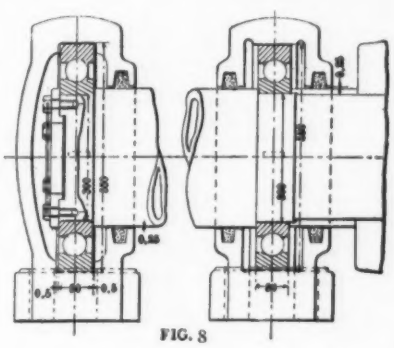


FIG. 8

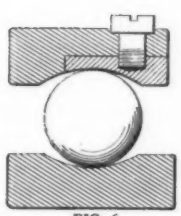


FIG. 6

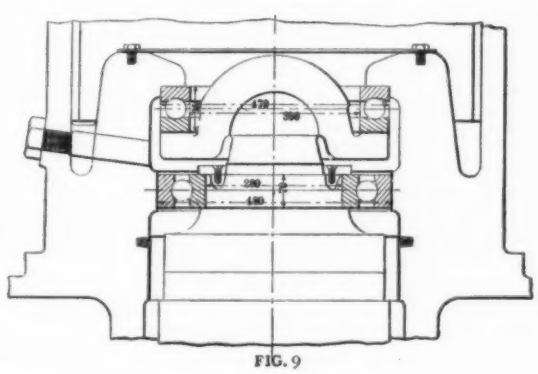


FIG. 9

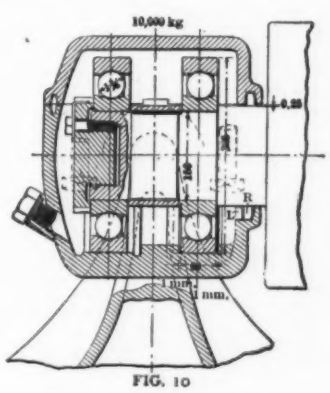


FIG. 10

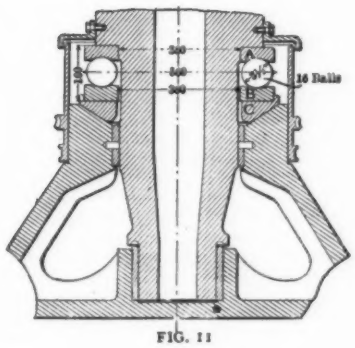


FIG. 11

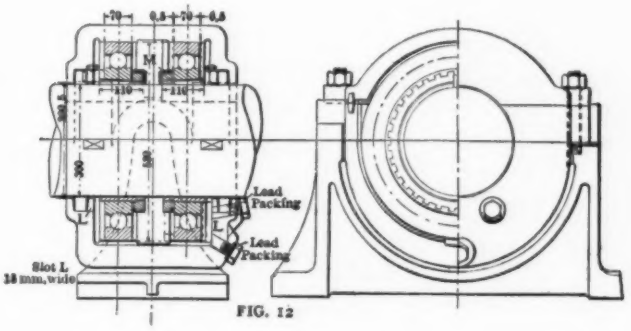


FIG. 12

APPLICATION OF BALL BEARINGS TO HEAVY WORK.

* By scaling the drawings we find the balls to be about 50 mm. in diameter.—ED.

of the weight actually sustained, but is supplied to take care of the shock of firing.

In the domain of electrical engineering are flywheel converters used in German mine hoists carrying rotating loads from 4 tons at 1,200 revolutions per minute to 22 tons at 500 revolutions per minute, some on one and others on two ball rows per journal. The arrangement here shown for 22 tons, Fig. 12, is similar to that employed for calenders with equalizer for two ball rows, differing in that the shaft projects through the journal and that the ball races are clamped to the unchanged journal of the old shaft by so-called "adapters." Owing to the relatively high speed and necessity for a high degree of safety in this class of service, unusually large bearings are selected.*

THE MINOR NAVIES OF THE WORLD.

THERE is, perhaps, no subject more discussed in the present day than that which has been denominated by the great American seaman-author, Capt. Mahan, as sea-power. As steam-power has increased, and as year by year the steamship has grown in both size and swiftness, the nations have discovered that where in the old sailing days they were self-contained entities, producing for their own consumption those articles necessary for their existence, to-day a much wider application of the term "necessaries" has sprung into existence. Articles which but a couple of decades ago were the luxuries of the rich are now the common objects of the coster's barrow in the great capitals and wealthy cities of our complex civilization, and all this has meant an enormous increase in sea carriage among the nations, the erstwhile self-containedness of which has been exchanged for that interdependence and commercial cosmopolitanism which is the principal feature of the age in which we live. This world-wide commerce, and the different class of vessel which is now engaged in it, have altered many features in the sea routes of the world, of which one instance may suffice; ten or, at the most, fifteen years ago Gibraltar was a great port of call for all steamers bound outward "up the Straits," or homeward from the Mediterranean, for the purpose of re-bunkering; and where, in those not very far distant days, fifteen or twenty steamers would enter or leave the port daily, at present one or two have taken the place of the larger number, and those which now make regular calls are nearly all of the big liner class, who never coal in the bay. Nowadays the humblest tramp carries coal sufficient to take her from London or Liverpool to Port Said, and the once-flourishing coal trade is a thing of the past in Gibraltar. The day of the giant merchantship is also the day of the leviathan man-of-war; the tonnage and horse-power of the "Great Eastern," so long the standard of all bigness, have now long since been surpassed, and concomitantly the size of warships has increased until, in the present, we are confronted with the accomplished fact of the "Dreadnought," and the plans of France, Germany, Japan, and the United States to follow where England has led. Competition in trade in the twentieth century seems to be followed by further competition in armament as surely as the night follows the day; and the taxpayer, who gasped at the idea of a warship costing several millions, has now to steady his nerves sufficiently to accept the fact that the powers that be now consider an expenditure of double that sum necessary on the vessel which is destined to guard his hearth and home. Building programmes for navies have increased beyond the wildest dreams of even ten years ago, and we may note, without any intention of entering into any controversy on the subject, that it is Great Britain which has shown the first signs of weakening in that competition in which, whether she likes it or no, she is bound for the sake of her very national existence to remain at the head. The fact of this strenuous striving after an equality with England on the part of other powers renders an examination into the force at the disposal of the minor navies of the world all the more interesting, as, in the event of some Titanic sea struggle happening, the possible exhaustion of the combatants might render the aid of those whom Great Britain regards at present with a certain measure of contempt an asset by no means to be despised. It is not really very difficult to separate the great from the small in the matter of sea-power, as the former category is really a small one, which comprises Great Britain, the United States of America, France, Japan, and Germany; Italy and Austria can be placed intermediately, and we then come to those nations which are not regarded as serious rivals by any of those just mentioned. Of Russia it is, of course, unnecessary to speak at present.

Those fine seamen, the Scandinavians, properly come first in consideration of minor navies, and their requirements in the shape of men-of-war are rightly and sensibly limited to ships destined to defense. They have at present no ship in commission larger than the "Aran" class, of which there are four; their displacement is 3,650 tons; length, 287 feet; beam, 49¼ feet; maximum draft, 16 feet; these vessels carry two 8.2-inch 45-caliber, and six 6-inch guns, ten 3-pounders, two 1-pounders, and two submerged torpedo tubes. The "Distrigheten," of 3,500 tons, has a similar armament, except that she carries 6-pounders instead of 3-pounders; the "Svea" class, of three ships, are of 3,300 tons, with an armament different from the others, in that they carry one 8.2-inch gun less, one more 6-inch gun, and one more 6-pounder. The "Odin," "Thor," and "Niord," of 3,400 tons, and which date from 1879, 1898, and 1899 respectively, conclude the list of Swedish warships other than torpedo craft; their armament consists of two 10-inch and six 4.7-inch guns, ten 3-pounders, and two 1-pounders, and one submerged torpedo-tube. A cruiser—the "Fylgia," laid down in 1905, of 4,060 tons—is building, as also a coast service battleship—"Oscar II."—of 4,275 tons. The torpedo craft comprise five torpedo-gunboats, two destroyers, and some torpedo-boats.

The sister kingdom of Norway possesses two cruisers—the "Norge," and "Eidswold"—of 3,800 tons; two—the "Harold Haarfagre," and "Tordenskiold"—of 3,400 tons; and three torpedo-gunboats. Norway and Sweden have need for navies owing to the propinquity of Russia and Germany; and although their force is small, it is said to be, as might be expected, extremely efficient; and in the stormy and foggy waters in which they are called upon to operate there is no doubt that these few Scandinavian vessels would prove a hard nut to crack.

Denmark possesses three coast-service battleships of the "Heriuf Trolle" type, of 3,470 tons, carrying three 9.4-inch, and four 6-inch guns, ten 6-pounders, four 1-pounders, five machine guns, and five torpedo tubes. The" Skjold," dating 1896, is 2,160 tons; but the remaining craft, the "Valkyrien," of 3,020 tons, built in 1880; "Tordenskjold," 2,580 tons, 1880; "Iver Hitfeldt," 3,200 tons, 1886; and "Helgoland," 5,370 tons, 1878, may be dismissed as being absolutely without fighting value in the present day. There are no seamen in the world for whom the British have had a greater respect than for those of the Low Countries, as Van Tromp, De Ruyter, and many a stout Dutchman besides caused much trouble in the days of old; for was it not the Dutch who burned British vessels in the Medway? And there are captured English flags hanging in the cathedral at Amsterdam to-day. But the days when Holland could measure herself with England are gone; and the old amphibious breed, sheltering behind the dykes which keep out the German Ocean, are to-day possessed with a lively fear of a foe which may come from the south, and not from the north, a foe which desires, above all things, ships, colonies, and commerce, and which casts covetous eyes on the ports of Belgium and Holland. Maritime expansion on the large scale is not possible for either a mercantile or an imperial navy, and Rotterdam and Antwerp in German hands would make a nice commencement of that new state of affairs when Germany is to reign supreme from the North Sea to the Adriatic. But meanwhile Belgium is neutralized by European agreement, and the Dutch, as all the world knows, have before now preferred that the North Sea should swallow their territory sooner than that it should remain in the possession of any save themselves.

Meanwhile the navy of Queen Wilhelmina is no very formidable affair, as the largest battleship, the "Tromp," is but of 5,300 tons, carrying two 9.4-inch and four 6-inch guns, twelve 12-pounders, and four 1-pounders, and three torpedo-tubes. There are also the "Koningin Regentes," "De Ruyter," and "Hertog Hendrik," of 4,950 tons, carrying two 9.4-inch and four 6-inch guns; the "Evertzen," "Piet Hein," and "Kortenaar," of 3,520 tons, carrying three 8.2-inch, and two 6-inch guns; the "Koningin Wilhelmina der Nederlanden," of 4,600 tons, with one 11-inch, one 8.2-inch, and two 6.8-inch guns; and besides the six cruisers of the "Holland" class, of 3,950 tons, carrying two 6-inch 40-caliber, and six 4.7-inch guns. These, with some torpedo-boats, make up the naval strength of Holland.

Another old antagonist of the Dutchman—the Spaniard—comes next on the list; but since the war with the United States, in 1898, very little has been done in the Peninsula to remedy the state of weakness to which that conflict reduced her: the "Pelayo," of 9,950 tons, dates from 1887, and can accordingly be hardly considered seriously in the present day; the "Princesa de Asturias" and "Cataluna," of 7,000 tons, date respectively from 1896 and 1900, and carry two 9.4-inch, and eight 5.5-inch guns; the "Emperador Carlos V.," of 9,200 tons (1895), "Lepanto," 4,826 tons (1892), and four small cruisers complete the list of Spanish naval power.

Portugal possesses the "Vasco da Gama" (which dates from 1875, but was reconstructed at Leghorn in 1902), of 2,500 tons; the "Dom Carlos I.," of 4,100 tons, dating from 1898, carrying four 6-inch, and eight 4.7-inch guns; the "Rainha Dona Amelia," of 1,665 tons; the "Adamastor," of 1,750 tons; and the "Sao Gabriel," and "Sao Rafael," of 1,800 tons. There are, in addition, a number of gunboats, of no value whatever.

The Turkish fleet may be mentioned *en passant*. But it is to be imagined that no one—least of all the Yildiz Kiosk—is likely to take this as a serious force; it can be a matter only for wonderment why persons so shrewd as the Sultan and his environment should ever have wasted money in the purchase of ships for the purpose of allowing them to slowly molder into decay at the Golden Horn.

The Greeks are the possessors of three battleships, of 5,000 tons—the "Psara," "Spetsai," and "Hydra." Roumania is credited with a cruiser—the "Elizabeth," of 1,320 tons; and Bulgaria with a torpedo gunboat, of 715 tons. Even an alliance comprising all these powers would not materially alter the balance of power in Europe. This completes the tale of the ships belonging to the minor European powers; but we have yet Asia and America with which to deal. In the former continent China possesses the "Hai-Chi," of 4,300 tons; the "Haiyung," "Hai-Shew," and "Hai-Shen," each of 3,000 tons; and some gunboats and torpedo craft. But China, although, like Japan, she has had in her time the services of most able British naval officers to help to train her fleet, has not profited by the instruction given, and as soon as the Englishmen were withdrawn, the ships and crews were allowed to drift back into the state of hopeless incompetence which obtained before. Siam has one cruiser—the "Maha Chakrkri"—and a few gunboats.

And now in considering the minor navies of the world there remains America, in which continent there are a good many vessels of war apart from the fleet of the United States, which is projected to be, as all men know, only second in power and importance to that of Great Britain herself. Although, taken singly and compared with European navies, America presents nothing very formidable from the point of view of armed maritime force, still, if we collect together the warships of Argentina, Brazil, and Chili, we shall find that collectively they might prove a not unimportant addition to the strength of the United States in repelling any attempts to violate the hegemony which that power has decreed shall exist on the western side of the Atlantic Ocean. Argentina possesses the "Independencia," and "Libertad," of 2,336 tons, carrying two 9.4-inch, and four 4.7-inch guns; "Almirante Brown," of 4,627 tons, with ten 6-inch guns; "Pusyredon," and "General Belgrano," of 7,000 tons, with two 10-inch, and ten 6-inch guns; the "Garibaldi," and "San Martin," of similar armaments; the "Buenos Aires," of 4,500 tons, with two 8-inch, and four 6-inch guns; "Nueve de Julio," of 3,500 tons, with four 6-inch, and eight 4.7-inch guns; "Vinte-Cinco-de-Maio," of 3,200 tons, with two 8.2-inch, and eight 4.7-inch guns, besides some old vessels and torpedo craft. The naval authorities of Argentina have under consideration designs and tenders from the leading shipbuilders for the construction of several large vessels, including battleships.

Brazil has the "Riachuelo," of 5,700 tons, but as her date is 1883, she can hardly be reckoned as an efficient warship; the "Deodoro and Floriano," of 3,162 tons, carrying two 9.2-inch, and four 4.7-inch guns; "Barrozo," 3,450 tons, with six 6-inch, and four 4.7-inch guns; "Tamandare," of 4,537 tons, with ten 6-inch, and two 4.7-inch guns; also old vessels and torpedo craft. There was recently ordered by the Brazilian Admiralty three battleships, two of which are to be built by Sir W. G. Armstrong, Whitworth & Co., Limited, and one by Messrs. Vickers' Sons & Maxim, Limited, who, we understand, will construct the propelling machinery for all three.

Chili has the "Capitan Prat," 6,900 tons, with four 9.4-inch, and eight 4.7-inch guns; "O'Higgins," 8,500 tons, with four 8-inch, and ten 6-inch guns; "Esmeralda," 7,000 tons, with two 8-inch, and sixteen 6-inch guns; "Blanco Encalada," 4,420 tons, with two 8-inch, and ten 6-inch guns; "Chacabuco," 4,300 tons, with two 8-inch, and ten 4.7-inch guns; "Ministro Zenteno," 3,600 tons, with eight 6-inch guns; also old ships and torpedo craft. Chili, like her neighbors, aims at the strengthening of her fleet, and, as in the case of Argentina, has plans and prices of ships before a naval commission; but the great financial loss due to the earthquake must intensify a situation not very encouraging, so that the government may be disposed to pause in the matter of naval expansion. Such a decision might influence Chili's great rivals of Argentina, inducing them also to defer, on new warships, the expenditure of capital which must be borrowed in any case.

Belgium, Cambodia, Colombia, Costa Rica, Ecuador, Egypt, Hayti, Morocco, Mexico, Persia, Peru, San Domingo, San Salvador, Sarawak, Uruguay, Venezuela, and Zanzibar are possessed of vessels of a nominally warlike character, which fly the flags belonging to these states, but none of which is of the smallest value. There are also a certain number of merchant vessels subsidized for use in case of war; but as these belong to the Great Powers, they do not come within the scope of the present article. Although these minor navies exist, it would seem somewhat problematical if they will continue to do so in the future; more and more, as time goes on, does the power of the purse assert itself in maritime affairs; at sea as well as on shore the wholesale man seems destined to oust or to gobble up the retail dealer; the small man in any walk of life at the present time seems in danger of absolute extinction, and, as with commerce, so it is with armaments. Powers like Spain, Holland, Brazil, or Chili may own men-of-war which are comparatively modern, and consequently useful; but as time goes on the life of warships seems to shorten more and more, and the constructive marvel of a decade ago is hopelessly *declassé* to-day. Estimates for new construction have to be faced by the Great Powers in that struggle for existence which is leading them no man knows whither; but so great is the burden, so appallingly does expense mount up nowadays in the building of even moderate-sized cruisers, that it is very doubtful if the minor powers will be able to face the taxation necessary for the upkeep of their fleets. It may be that national pride will nerve them for the making of the sacrifice; but even if made, it is hard to see of what value it will be when it is remembered that the struggle is unceasing and year by year more costly; the common sense of the matter would appear to be that, as that nation is said to be happy which has no history, it would be better to give up attempting to make it by futile expenditure upon naval armaments.—Engineering.

Rain-Resisting Plaster Casts.—This recipe is useful for statues and decorative plaster objects exposed in gardens to the inclemency of the weather. First smear the object with a coat of boiled linseed oil. When this is absorbed, add one-tenth of its weight of litharge and apply a second coat.

* The use of the scale shows these balls also to be about 50 mm. in diameter.—ED.

THE FIXATION OF ATMOSPHERIC NITROGEN.

THE thirteenth annual meeting of the German Bunsen Society was held at Dresden and was attended by a large number of members of the society, including Nernst, Foerster, Le Blanc, and other leading German electro-chemists. The recently-held International Congress of Chemists at Rome no doubt interfered to some extent with the attendance at this year's meeting of the Bunsen Society.

Following the plan adopted at last year's gathering, a number of papers upon one of the more important subjects of scientific and technical interest at the present time had been arranged, the subject selected for this year's meeting being "The Fixation of Atmospheric Nitrogen." These papers were read and discussed at the first business meeting. As this subject is of considerable interest to chemists, electricians, and engineers in all countries, the papers and discussions upon it have been dealt with somewhat fully in this report. More detailed reports of these papers and of the discussions upon them will be found in the Zeitschrift für Elektrochemie, the official organ of the society, in the issues for June and July.

Prof. F. Foerster, of Dresden, introduced the subject, "The Fixation of Atmospheric Nitrogen," with a lecture dealing with the chemical and physical properties of nitrogen and its oxides, and outlining briefly the nature and difficulties of the problem presented to electro-chemists for solution. It was pointed out by the lecturer that nitrogen was one of the most inactive of the elements at the normal temperature, and that only at very high temperatures did it become chemically active and able to enter into combination with oxygen.

The importance of nitric acid and of its salts—sodium and potassium nitrates—in the arts and industries was next referred to, and the laboratory production of nitrogen oxides by Cavendish and Priestley in 1780 by means of electric spark discharges in air was described. Bunsen also observed the formation of nitric oxide when exploding mixtures of hydrogen with excess of air. The experiment can be easily repeated, and the formation of the brown N_2O_4 observed, when direct current at 60 volts to 70 volts E. M. F. is allowed to spark in air, using iron-wire electrodes. The oxidation or combustion of nitrogen produces no heat, and in this respect it differs from the usual type of combustion. The flame is therefore extinguished unless fed with a continuous supply of electrical energy. The reaction is, however, a thermal and not an electrical one, and the only duty of the electric current is to maintain the nitrogen at the temperature at which it becomes chemically active toward oxygen. The fixation of nitrogen in the form of nitride by passing the gas over heated cerium, boron, titanium, magnesium, or calcium is another method of great chemical interest. Technically, however, it is of no importance, since the recovery of these elements in the metallic state is too costly. The fixation of nitrogen by means of calcium carbide—worked out by Dr. Franks—is a third method, of more promise. In this case calcium cyanamide—$CaCN_2$—is produced, and the compound is of direct value as a manure, apart from its value as an intermediate product in the manufacture of nitrates and ammonia. Prof. Foerster concluded with some figures showing the importance of nitrogen to the agricultural industry. In 1900, 1,300,000 tons of Chili saltpeter was used; in 1905, 1,500,000 tons. Of this enormous total Germany consumed about one-third. In 1900 the total world production of sulphate of ammonia was 500,000 tons, to which total Germany contributed 150,000 tons.

Of this total world production of artificial nitrogen compounds, either in the form of nitrates or of ammonia, agriculture absorbs 75 per cent, and the total value of these artificial manures in 1900 amounted to 270,000,000 marks, or £13,500,000.

Prof. Nernst, of Berlin, then read a paper upon "The Equilibrium and Reaction Velocity Ratios for Nitric Oxide Formation." A proof of the thermal nature of this reaction is found in the fact that the union of nitrogen and oxygen is observed as an explosion phenomenon with the mixed gases. The chemical laws of mass reaction can therefore be applied to the problem involved in the calculation of the ratios desired.

Both of these constants are of the highest importance for the technical industry, since it is requisite to obtain a concentration of nitric oxide as high as possible in the final gases, in the minimum of time. For calculation of the equilibrium ratio the usual equation

$$K = \frac{(NO)^2}{(O_2)\ (N_2)}$$

can be applied. In this equation K is a constant independent of the mass of the gases, but dependent upon the temperature; while the chemical symbols within brackets represent the pressures of the component parts of the gas mixture. The larger the value of K, the greater will be the amount of NO obtained from the same gas mixture. It is important for technical purposes to calculate the point at which increased value of K ceases to be remunerative, owing to the increased cost of the electrical energy required for producing the higher temperature which causes it.

In order to obtain the data required for calculating this value, Nernst led air through a platinum or iridium crucible maintained at the desired temperatures by means of an electric furnace. The gases passing through the crucible were led through a platinum capillary tube, in order to obtain rapid cooling of the gas mixture, and were then analyzed to ascertain the NO contents. This rapid cooling is of importance, since otherwise portions of the already formed NO would be again decomposed—a result due to the declining value of K as the temperature fell.

By rapid cooling of the gas mixture, however, there is what may be called a "freezing in" of the value K, and the composition of the cooled gases is practically the same as at the moment they issued from the heated crucible. From the data obtained by this method the value of K can be directly obtained.

Another method used for checking the results, rests upon the observation of the influence of pressure upon the time of explosion and temperature obtained in "Knallgas" explosions.

For calculating the speed of reaction ratio the following equation was used:

$$K = \frac{v_1}{v_2} = \frac{k_1}{k_2} = \frac{(NO)^2}{(O_2)\ (N_2)}$$

in which k_1 and k_2 represent the constants for the speed of combustion and dissociation of NO. Now k_1 can be calculated, K is known, and thus k_2 can be ascertained; and from these data the general equation

$$\log.\ k_1 = A\ T + B + \frac{C}{T^2}$$ was obtained. At high temperatures the last member of this equation disappears, and one thus obtains a straight line ratio between the value for k_1 and the temperature. By use of this method one can, therefore, obtain the time required for the production of a given amount of NO.

Using x to denote the percentage of NO in the exit gases for various temperatures, the following values were obtained:

Values of x.			
Calculated.		Observed.	Interpolated.
T. deg.	x.	T. deg.	
1,500	0.10	1,811	0.37	0.35
1,800	0.34	1,877	0.42	0.43
2,000	0.61	2,023	0.52	0.64
2,500	1.79	2,033	0.64	0.67
3,000	3.57	2,195	0.97	0.98
		2,580	2.05	2.02
		2,675	2.23	2.35

The following are the values obtained for the establishment of a state of half equilibrium: for complete equilibrium, infinite time is, of course, required:

T deg.	k_1.	t.
1000.....	40	81.68 years.
1500.....	37,800	1.2 days.
1900.....	$9.06.10^6$	2.08 minutes.
2100.....	$1.40.10^8$	5.06 seconds.
2500.....	$3.37.10^{10}$	$1.06.10.^{-2}$ seconds.
2900.....	$8.07.10^{12}$	$3.45.10.^{-10}$ seconds.

From this table it is seen that the time required diminishes enormously with the increase of temperature. It is nevertheless impossible in actual practice to obtain a gas containing more than 3 per cent of NO, for the cooling of the gases cannot be completed quickly enough entirely to prevent dissociation.

In the discussion upon Nernst's paper, the question was raised whether a gas mixture containing 50 per cent each of oxygen and nitrogen would yield better results than ordinary air for NO production.

Nernst replied that by this plan the yield could be improved by 20 per cent, but that the cost of preparing such a gas mixture would not be balanced by the gain in output of NO.

Prof. F. Foerster, of Dresden, followed with a paper upon "The Technical Methods for Carrying Out the Combustion of Nitrogen." The author commenced by stating that theoretical considerations clearly indicated the lines upon which the technical methods must be developed. The gas mixture must be heated to the highest possible temperature, and then must be cooled with the greatest possible rapidity.

Muthman and Hofer had found in their experiments that the yield of NO decreased with the increase of electric energy put into the arc. Researches by Brode helped to explain this anomaly. The electric arc consists of a very hot inner core, and an outer "aureole" of flame, of lower temperature. This halo increases in extent, however, with increase in the electric energy put into the arc. Now NO is only formed in the inner flame; the temperature of the halo causes its dissociation. Therefore, increase in the extent of the halo causes increased dissociation. For this reason better results were obtained in the early trials with spark discharges—as in the case of these, the second zone of flame is of small dimensions.

But an enormous number of sparking points is required, since each represents a very small amount of electrical energy. Bradley and Lovejoy attained this number by designing a drum covered with points, which revolved slowly inside another drum similarly provided on its inner surface. With this apparatus they obtained 88 grammes HNO_3 per kilowatt hour, and a concentration of 2 to 3 per cent NO in the issuing gases. Using current at 10,000 volts pressure the apparatus required only one ampere, and attempts to use a larger current only produced the halo of lower temperature which it was necessary to suppress. To obtain a large amount of nitric acid from the air by this method would have required, therefore, the construction of many hundreds of these revolving drums; and as they were complicated and costly, the Bradley and Lovejoy process failed.

A sparking process for the manufacture of nitric acid might be worked with the aid of condensers, but hitherto electrical condensers have not proved durable when in constant use. Inventors in this domain have therefore turned to "flame-arcs" for provision of the heat required, the essential condition of this use being that the arc should be continually in movement, or should be rapidly extinguished and re-made. This condition can be best attained by means of a magnetic field, and by use of alternating current for forming the flame-arc. By this method of working the flame-arc is made to take the shape of a disk, and it has been applied practically to NO production by Messrs. Birkland and Eyde. Their apparatus or furnace consists of a case 1 meter high and 1 meter broad, within which, by means of an alternating current and a magnet, a disk of flame 2 meters in diameter is produced. The whole interior of the case is, in fact, filled with a sea of flame, and into this the air to be consumed is led. The furnace takes 500 kilowatts of electrical energy, 10 per cent of this being required for the production and maintenance of the magnetic field. The flame-arc is produced by an alternating current at 5,000 volts; 25 cubic meters of air are led per minute through the flame, and a concentration of 2 per cent NO is thereby attained in the issuing gases.

From 70 to 83 grammes HNO_3 per kilowatt are obtained with this furnace in constant work, this being equivalent to 500 to 600 kilogrammes per kilowatt year. Taking the cost of the kilowatt hour at 0.60 pf., this is equivalent to 0.29 mark (3.4d.) for the electrical energy required to produce 1 kilogramme of nitrogen in the form of nitric acid; whereas in sodium nitrate—the Chili saltpeter of commerce—the same amount of nitrogen costs 1.25 marks (1s. 3d.).

In Norway, the nitric acid is converted into calcium nitrate, or into the basic nitrate of lime, the latter compound having proved a good fertilizer for agricultural purposes. The annual consumption of 1,500,000 tons of nitrate of soda would require 2,500,000 horse-power to produce by the method just described; but the waste gases of the blast furnaces now in operation in Germany alone would generate 500,000 horse-power if utilized for this purpose.

The author then discussed the theory of the above methods for producing nitrate from the air, and stated that from the results of experiments carried out by himself, with direct and alternating currents, he had concluded it was the "amount" of electrical energy and not the manner of discharge that influenced the results obtained. Haber had calculated that with a temperature of 4,200 deg. C., and rapid cooling of the final gases, a yield of 212 grammes HNO_3 per kilowatt hour might be attained; while with a temperature of 3,200 deg. C., only 93.5 grammes were attainable. The former figure of 212 grammes is, in the author's opinion, too high; but the lower limit of 93.5 grammes has already been nearly attained in practice, and an increase of this yield will only come by use of methods which can communicate a higher temperature to the air sent into the furnace. Further progress in the industry is, therefore, a question for electricians rather than for chemists, although by use of a 50 per cent mixture of nitrogen and oxygen, under pressure, a slight increase in the yield might be obtained.

Such a 50 per cent mixture of oxygen and nitrogen might be won by the distillation of liquid air, and the residue of pure nitrogen could then be utilized for preparation of calcium cyanamide by the Frank and Caro process.

Bodenstein, Eskales, Nernst, Brode, and Stavenhagen joined in the discussion on this paper.

The next paper of this series, upon "The Fixation of Atmospheric Nitrogen," was contributed by Prof. Le Blanc, of Karlsruhe, and dealt with the estimation of nitric oxide—NO—in air. The author stated that the literature upon this subject was scanty and inaccurate.

The method of estimating NO, usually described, was to lead the gas mixture through water, and to determine the nitrate and nitrite present after the absorption. According to the authorities, equivalent amounts of nitrate and nitrite would be produced, as shown by the chemical equation:

$$N_2O_4 + H_2O = HNO_2 + HNO_3.$$

The author had found, however, that several conditions influence the results obtained, and that the character of the flame, the length of time during which absorption is occurring, and the nature of the absorbent each influenced the proportion of HNO_2 to HNO_3 obtained in the final solution. Although the difficulties in the way of obtaining a correct estimation are therefore great, by the choice of suitable conditions for the absorption a quantitative estimation of the nitrate present in solution is possible. The author finally gave reasons for believing that N_2O_3 and NO_2 are also present at times in the gases pressing from the inner zone of the arc.

The paper by Prof. Klaudy, of Vienna, was upon "The Technical Methods for Converting the Nitrous Gases into Nitric Acid and Its Salts." The author stated that the results obtained in regular work by the larger installations for nitric acid production from the air gave a concentration of 27 grammes NO per cubic meter of air. This was equivalent to 21.6 liters of NO per 1,000 liters of air, or 2.16 per cent, and corresponded to a temperature of 2,600 deg. C. in the interior of the furnace. This yield of NO corresponds to 600 kilogrammes HNO_3 per kilowatt year; but owing to the dilution of the escaping gas, only a portion of this total can be recovered as nitric acid.

In Norway, the kilowatt year in certain localities can be obtained by water-power for 20 M. (£1), while in Switzerland and Austria it costs 40 M. (£2), and at Niagara 80 M. (£4). Power gas installations and small water powers cannot, therefore, compete in this

new industry, although blast furnace gases may have a future. Taking the above figures as basis of the calculation, the author finds that in Norway 1 kilogramme of nitrogen in the form of NO_2 costs only 0.15 M. (1.8d.), while in the form of sodium nitrate or nitric acid it costs from 1.15 M. to 1.90 M.

Prof. Frank, of Charlottenburg, was to have read the last paper upon this subject, dealing with the Frank and Caro method of fixing atmospheric nitrogen by means of calcium carbide. Prof. Frank, however, did not attend the meeting, and below we give an abstract of the paper he delivered on the same subject at Rome, a fortnight earlier. Calcium carbide is formed in the usual manner by heating lime and coke in the electric furnace, and over this product, while still hot, nitrogen obtained by the fractional distillation of liquid air is passed. This gas is absorbed by the heated calcium carbide with formation of a compound having the formula $CaCN_2$, and known as calcium cyanamide, or "Kalkstickstoff." This product contains nitrogen in a form which renders it available for other chemical reactions, and it can be used directly upon the soil as a chemical manure, or as the raw material of several secondary manufactures. Among these latter, the production of pure ammonia, pure nitric acid, ammonia salts, cyanamide, dicyandiamide, urea, indigo, and a new compound for hardening steel, "Ferro-dür," may be named. Dicyandiamide has been used in the manufacture of powders for rifles and cannons with good effects, since it reduces the combustion temperature, and, therefore, the wear and tear on the rifling of the gun.

As regards the industrial development of the Frank and Caro process, three works have been planned for operation on a large scale in connection with water-power developments in Italy, and the first of these, located in Plain d'Orte, is already in operation. Other works are to be erected in France, Spain, Switzerland, and Norway at an early date. As regards yield, the best results obtained so far represented the fixation of 330 kilogrammes of nitrogen with the expenditure of one E.H.P. year; but it is hoped, as more experience is gained in the practical working of the process, that this yield, equal to 43 per cent of the maximum possible, will be greatly increased.—Engineer.

THE PROGRESS AND LOGICAL DESIGN OF REINFORCED CONCRETE.*

By Ross F. Tucker, M.Am.Soc.C.E.

Those who are under the impression that the present popularity of reinforced concrete is largely a fad may be interested to note the progress of this type of construction since its inception in 1885, in terms of the production of Portland cement in the United States. In 1882 the output of Portland cement was 82,000 barrels. At this time, reinforced concrete was unknown, and the value of Portland cement concrete as a structural material was not dreamed of. Natural and Rosendale cement had the field practically to themselves and concrete, where it was used at all, was confined almost wholly to foundation and underground work. A glance at the accompanying illustration, Fig. 1, will show at once the enormous stride that the industry has made in a short quarter of a century. In Fig. 1 is shown the production of Portland cement in the United States at intervals of five years from 1880 to the present time. At the side is shown the development of the concrete industry in the same periods of time.

In 1885, Ernest L. Ransome, then of San Francisco, invented the twisted bar and demonstrated the principle underlying all reinforced structures whereby it is possible to incorporate steel bars in a mass of concrete in such a manner as to enable the concrete to withstand transverse loads. It will be noted by reference to the figure that at this time the production of Portland cement in the United States was 150,000 barrels. From 1885 to 1890, Ransome was engaged in applying his discoveries to works of the most elaborate and extensive character. When we take into consideration that, at that time, the subject of reinforced concrete was in a most elementary experimental stage, and that there were no accurate formulae or known

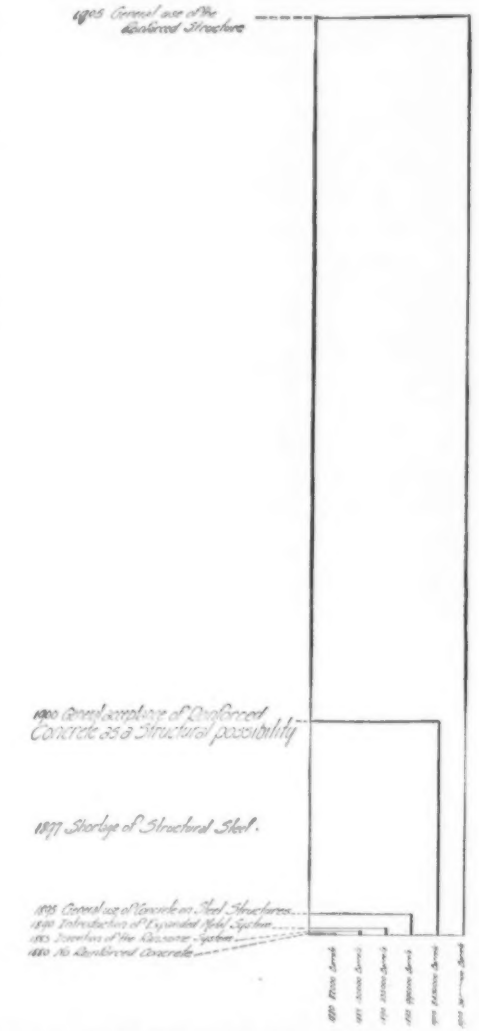

1905 General use of Reinforced Structure
1900 General acceptance of Reinforced Concrete as a Structural possibility
1897 Shortage of Structural Steel.
1895 General use of Concrete on Steel Structures
1890 Introduction of Expanded Metal System
1885 Invention of the Ransome System
1880 No Reinforced Concrete

Fig. 1.—SHOWING PROGRESS OF REINFORCED CONCRETE IN TERMS OF THE PRODUCTION OF PORTLAND CEMENT IN THE UNITED STATES.

valuations for determining concrete design, and that the appliances for making and handling concrete were of a primitive kind, we can appreciate the difficulties with which he had to contend, and can bestow the greater credit and honor upon him for the courage and splendid mechanical and engineering ability which he displayed in undertaking the construction of steel concrete buildings of such magnitude in a country subject to earthquakes. Among the structures above referred to are the Museum Building (interior shown in Fig. 2), and Girls' Dormitory (Fig. 3), at Stanford University; the interior of Academy of Sciences (Fig. 4), the building for the Pacific Borax Company, and the Tubbs Cordage Works, and the value of his discoveries has been further accentuated by the fact that during the recent great earthquake in California all of the above structures, comparatively crude as they were in design, came through the ordeal practically unscathed, where buildings of brick and stone in their immediate vicinity were entirely wrecked. In 1890 Ransome determined to introduce his ideas throughout the country, and for a considerable time thereafter, the writer was engaged in lecturing before technical societies and architects and engineers generally on the subject of reinforced concrete and the possibilities of that type of structure. While these ideas were all of great interest to the technical public, they were so new to the building world at large that it was only here and there that they gained a foothold. The steel frame structure by this time had been brought to a high degree of development and architects and engineers, while interested in the possibilities of reinforced concrete, were loth to give up the steel skeleton and adopt a type of construction with which they were so entirely unfamiliar. The lesson, nevertheless, had its effect. About this time came the introduction of expanded metal and the mesh systems of concrete construction, which enabled the architects to retain their steel structures and use concrete for the filling and arch work between beams in place of brick work and terra cotta. These methods enabled the architects to use concrete in a conservative manner and to become acquainted with its structural properties without abandoning the steel frame which constituted the main structural basis of their design. In this period, from 1890 to 1895, the production of Portland cement progressed from 300,000 barrels to 900,000 barrels, and the lessons learned from the use of concrete in this respect led to its adoption in a large number of projects originally planned for other material.

From this time on the use of concrete grew very fast. In 1897 and 1898 there came a great shortage in structural steel. Deliveries were so uncertain and remote that engineers the country over were 'at their wits' end to find ways and means for fulfilling their designs, and they turned at once to reinforced concrete to help them out of their dilemma. European systems of reinforced concrete were introduced and engineers generally began to study the subject from a scientific standpoint, with the result that by 1900 the steel concrete structure was recognized generally as a structural possibility and its adoption was considered for every conceivable kind of problem. At this period, the production of Portland cement in this country had reached 8,400,000 barrels per annum. In the succeeding five years, however, the popularity of concrete and the confidence of the building public in its properties were demonstrated in a most astonishing manner, for the production of Portland cement sprang from 8,400,000 barrels in 1900 to 36,000,000 barrels in 1905.

Any one considering the progress of the industry, as noted, can hardly say that the reinforced structure is a fad, although it is to be admitted that concrete has been applied to many purposes for which it is not at all suitable. It is a fact now beyond dispute that the steel concrete structure has passed the experimental stage and has been adopted throughout the land as a building element of the greatest value. It is true, however, that much has yet to be done in the education of the architect and engineer and in the use of concrete in a logical manner and for its real value. Owing to the comparative youth of this type of building, architects and engineers generally have not as yet given any great attention to the development of design essentially suitable to reinforced concrete. It is the general practice to design in brick, stone, and steel and then to call upon a reinforced concrete engineer to reproduce a structure in reinforced concrete. This is an imperfect and unscientific method and unfair to the development of the true value of the concrete structure. The average architect and engineer is, as yet, too unfamiliar with the characteristics of concrete to design a structure solely from

Fig. 2.—INTERIOR OF MUSEUM BUILDING, STANFORD UNIVERSITY, 45-FOOT SPANS.
(Withstood earthquake perfectly.)

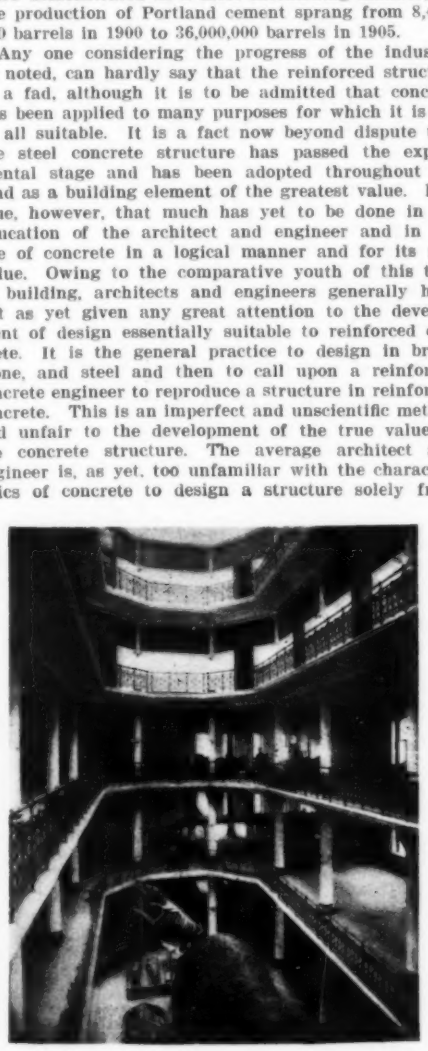


Fig. 4.—INTERIOR OF ACADEMY OF SCIENCES, SAN FRANCISCO.
(Withstood fire and earthquake.)

Fig. 3.—GIRLS' DORMITORY (ROBLE HALL) STANFORD UNIVERSITY.

* Read before the quarterly meeting of the Association of American Portland Cement Manufacturers.

that point of view. He thinks in terms of brick and steel, designs in brick and steel, and then attempts to adapt concrete to his structure. The architect who would design intelligently for reinforced concrete must think in terms of reinforced concrete, but up to the present time, the condition is similar to requiring a carpenter to think in the metric system when he has been all his life accustomed to figure in feet and inches. He must stop and translate and is unable to bring his mind to an adequate appreciation of his dimensions until he has so translated them. Reinforced concrete is a structural method possessing peculiar characteristics which are essentially its own, and any design which is to be carried out in this material should be adapted to its characteristics and qualifications. For instance, many have an idea that the cost of cement and the labor involved in the handling of concrete are the particular elements of cost in a concrete structure, whereas, as a matter of fact, the determining factor in the cost of concrete of whatever nature is the cost of the wood work and centering required for the carrying out of the design. The initial cost of a yard of concrete may be $5, but that same yard of concrete may be made to cost $40 by the addition thereto of elaborate forms necessary for the placing of the concrete in the position required in the design. On every structure projected for brick and steel, and afterward converted into concrete, the cost of concrete will vary for every yard from $5 to $40, depending upon the position in which it is placed and the elaboration of the forms necessary for the fulfilling of the design. It is, therefore, apparent that the greatest economy in the use of reinforced concrete is to be attained by keeping this fact in mind and designing the structure accordingly. The essence of economy in concrete work is the simplicity and duplication of forms, and this of itself demands the elimination of projecting members such as cornices, belt courses, and offsets to the largest possible extent. The reinforced concrete building must be essentially a plain building and its architectural effect must be developed by the study of the relation of the openings to the masses, together with the assistance of such color scheme as may be applied by the insertion in the face of the structure of tile or mosaic work in color masses suitable to the problem.

The above ideas are fairly well demonstrated in Fig. 5. It will be noted that the structure is of the skeleton type with the rectangle between the horizontal and vertical members filled in with block work or brick work, independent of the structure itself. Belt courses, cornices, and offsets are eliminated in a very large degree and shadow effects are obtained from projections of a simple character. Window openings are small and are protected by fire shutters, thereby rendering the building practically proof against the ingress of fire from neighboring buildings. Experience has demonstrated that fire is not to be feared so much from within as from without, and the essential to good design of a fireproof character is that the building may be inclosed from top to bottom. As an indication of the danger to which the steel structure is subjected, through inadequate fireproofing, attention is called to Fig. 6, showing the condition of steel columns on the third floor of the Bullock & Jones Building in San Francisco. These columns were protected in an inadequate manner with terra cotta, but the sweep of the fire through the building destroyed the covering and exposed the steel work in such a way as to buckle the flange plates and subject the building to very great loss. It is absolutely certain that had these columns been covered with concrete of the same thickness, nothing of this sort would have happened.

Many of the monuments of Rome, that have endured for more than 2,000 years, were built of a concrete far inferior to that which we use to-day—so inferior, in fact, and so different in method and material as to be hardly entitled to the name of concrete, as we know it, at all. Still these monuments, stripped of their facings of mosaic, tile, and stone by the ravages of time and conquest, still endure. What, then, may we expect of the great structures which we are building under the eye of modern science? It is certain that the concrete of our day will endure far beyond the life of any natural stone and it is not too much to hope and predict that when our architects have become acquainted with the true characteristics of this wonderful material, they will create a new architecture more original and more truly American than any we have attained thus far. The future is replete with possibilities. We have learned thoroughly how to make concrete strong, let us learn how to make concrete beautiful.

FIG. 5.—TYPICAL DESIGN OF STEEL CONCRETE WAREHOUSE.

FIG. 6.—INTERIOR OF BULLOCK & JONES BUILDING, SAN FRANCISCO, SHOWING CONDITION OF STEEL COLUMNS.

[Concluded from SUPPLEMENT No. 1607, page 25751.]

SOME FUNDAMENTAL CHARACTERISTICS OF MERCURY VAPOR APPARATUS.*

By PERCY H. THOMAS.

MERCURY VAPOR LAMP.

As a lamp, the mercury vapor apparatus has a number of interesting characteristics. Its great efficiency, which in long tubes reaches one-third watt per candle-power (exclusive of resistance losses), is obtained only when run under the most favorable conditions; for example, only with the proper vapor pressure, current, and tube diameter. Mercury vapor is a much more efficient material for light production than most other gases and vapors whether used alone or mixed. The addition of atmospheric air, for example, to mercury vapor, even in very small quantities, increases the voltage on the tube very much, thus increasing the energy supplied.

The spectrum of mercury vapor is, furthermore, one of the most complete and usable gas spectra; it contains a variety of colors in substantially equal proportions, chiefly an orange-yellow, a yellow, a blue and a violet, with a smaller amount of a green-blue. The only portion of the spectrum not pretty well represented is the red, which generally speaking is the least desirable color. The mercury spectrum has proved to be excellent physiologically, and extremely well adapted to most mechanical processes. It is possible, of course, by the addition of other gases to add red to the spectrum, which may then be quite prominent, especially if means are taken to condense a portion of the mercury vapor. In general, however, these combinations of gases are more or less likely to deterioration and alteration, and have a considerably lower efficiency than pure mercury vapor. For most purposes the color would not be more desirable with the addition of red.

Light Efficiency.—The efficiency of mercury vapor as a source of light follows a number of laws. (1) The watts per candle-power vary with the pressure of the vapor, having a minimum at a certain pressure. (2) It is nearly independent of the current strength within certain limits, in this case it being assumed that the pressure, temperature, etc., are constant. (3) Superheating the tube, and consequently that portion of the vapor emitting light, seems to have little effect.

It can be shown by the normal lamp voltage characteristic curve that the relation between the current and voltage of the operating lamp, that the most efficient light giving point is at, or nearly at, the point of lowest voltage on this characteristic. This is fortunate, since for purposes of regulation this is a most desirable point to operate the lamp. Above this most efficient point the pressure of the mercury vapor increases rapidly, and while also increasing the candle-power it increases the voltage in the tube in still higher proportion. Below this point the voltage on the lamp rises, probably partly on account of traces of residual gas not exhausted in the pumping, which causes a great dropping off of the quantity of light and the efficiency. These residual gases are here more

* Journal of Electricity, Power and Gas.

prominent on account of the lower mercury temperature and vapor pressure.

It is evident that the temperature of the mercury electrode and the pressure of the mercury vapor resulting from a given current will depend directly upon the air temperature surrounding the lamp. In the commercial types of lamp, however, the actual change in efficiency from change in atmospheric temperature is very slight throughout the practical working range.

Lamps may be made for various uses with different diameters of light-giving tubes. The diameter most commonly used and suited to 3.5 amperes is 1 inch, or a trifle less, in inside diameter. To give the same intrinsic intensity with other diameters the current should be varied in proportion to the cross section of the tube; that is, for a 2-inch tube we should require about 14 amperes. Since the voltage decreases as the diameter of the tube, and since at the same intrinsic brilliancy the quantity of light increases as the diameter on account of the larger surface, we should expect double the light and, double the energy consumed with the larger tube. It is found by measurement, however, that the larger tubes are somewhat more efficient so that there is a saving of 20 to 25 per cent on the efficiency for 2-inch over that of 1-inch tubes—inversely with smaller tubes and the appropriate currents. With smaller tubes, however, the difficulty of maintaining the negative alive becomes very much greater on account of the small current which, as already explained, is subject to momentary impulses tending to stop the flow of current.

There can be no one proper method of measuring the candle-power of a Cooper Hewitt lamp; first, on account of the fact that the color of the lamp is different from the color of any accepted standard, and because it is a spectral against a continuous spectrum; and secondly, because the light-giving tube is not a point, and the law of inverse squares does not hold except at very great distances. For commercial tests the candle-power of the lamp should not be measured at a great distance, since the lamp has a practical advantage it would lose were the candle-power measured at a considerable distance. Where it is important actually to define the candle-power of these lamps, the particular method of measurement to be used must be specified.

Alternating-Current Lamp.—The principle of the alternating-current lamp is generally well understood by this time. It is evident that during one alternation, current is supplied from one-half of the transformer secondary through the lamp tube back to the neutral point, and during the other alternation by the other half of the transformer secondary through the tube to the same point, and that the choke-coil in the negative lags the current over the zero points.

The light from the alternating-current lamp is practically equivalent to that from the direct current, since in the light-giving portion of the tube the light is substantially direct current.

On 25 cycles, by providing a larger choke-coil in the negative than is necessary in the 60-cycle lamp, the natural tendency to flicker with the period of the 25 cycles is eliminated.

Starting.—The method of starting in the type-C alternating-current lamp is an extension of that of the direct-current lamp and is of some interest. A small electrode or pin is placed in the head of the lamp, and connected to one of the positives through a rather high ohmic resistance. In starting, the lamp is tilted so that the mercury forms a continuous stream from the negative to the positive end, and is carried by its momentum up around the inside end of the tube until it touches the pin which is placed on the top side of the tube. On account of the irregularity of the flow of the mercury it here makes and breaks contact with the pin a number of times, each time causing a breakdown of the negative electrode resistance, either on the column of mercury or the pin. In the latter case the lamp will go out at the end of the alternation. If, however, the mechanical break at the pin occurs during such an alternation that the mercury column is the negative, the lamp will start to operate upon the pin, and that main positive electrode to which the pin is not connected as positive electrodes and the mercury stream as the negative. Then, on account of the starting resistance connected with the pin, the current will be immediately transferred from it to the corresponding positive, and the lamp is started. The lamp is then returned to its normal position and all the mercury flows back to the negative. If, now, there were no resistance between the pin and its positive electrode, and assuming the lamp to have been started during tilting by one of the breaks between the mercury and the pin, it is evident that if the mercury touches the pin again, the lamp will go out, since for this instant the flow of current does not enter the vapor at all (on account of the metallic connection between negative and one positive). That is to say, if it were not for this resistance which prevents current when once transferred to both main positives from being withdrawn by a subsequent connection between the mercury and the pin, the lamp would be started and put out and started again repeatedly. Only the last break between the mercury and the pin would count in starting, and we should fail to light the lamp more often than we succeed. As an actual matter of fact, lamps have been built which started practically every tilt, though the average commercial lamp is not expected always to light at the first trial.

MERCURY VAPOR CONVERTER.

The Cooper Hewitt apparatus may, as is well known, be utilized to supply direct current from an alternating current supply by virtue of the negative electrode resistance. No further description of the general method of accomplishing this result is necessary at this time. The converter may be run single phase, in which case a connection similar to that already described, except for starting circuits, is generally used, though it may be three-phase, four-phase, etc., in which case no choke-coil in the direct-current circuit is usually required.

Starting.—In a converter a very short vapor path is purposely provided, and the starting is easily accomplished by breaking a metal circuit in the vacuum as already described, for the current is here easily transferred from the starting to the main positive electrode. In a form of commercial bulb used for a single-phase converter together with starting circuits, there are two electrodes of mercury, one being the main negative and the other a starting electrode. By shaking these two together, passing current through and separating them, the negative electrode resistance is broken down and the voltage upon the main positive electrodes forces current to flow to the main negative. The supplementary positive should then be cut out of the circuit. Converters, however, can be started by starting-band and high-tension impulse, or by the direct application of sufficiently high potential.

In cases where the converter is to feed a storage battery, it will be noted that the electrical connection for the alternating-current lamp is not perfectly satisfactory, on account of the comparatively large direct current sent by the battery through the transformer winding when the negative and starting electrodes are connected, which is in the wrong direction to start the negative electrode as a negative. The high impedance of the sustaining coil prevents any considerable alternating current from flowing, but does not seriously limit the flow of direct current from the battery, which thus tends to make the starting positive a negative. The difficulty may be avoided by causing the battery to start the supplementary electrode as a negative, whereupon the main positives start operation with the supplementary as a negative, passing current through both the resistance and the battery, through a small shunt coil. If, then, a second connection is made between the starting and the main negative electrode, the current is shunted from this coil through the main negative, and on the second separation the main negative starts in the proper direction, as current is now passing against the battery instead of from it.

On account of the liquid character of the mercury, it has been found by experience that with one tilting operation two "makes" and "breaks" are ordinarily produced between the main and starting electrode so that the initial starting on the supplementary electrode and the transfer to the main negative occur almost together so as not to be distinguishable by the eye. The starting circuit should usually be cut out during regular operation. By making the shunt coil a magnet for tilting the bulb, the starting is automatic. This method has an advantage over other apparatus for automatic starting in that it is not necessary to operate any switches in the main circuit carrying the heavy current; the only cut-out that is necessary is the disconnection of the starting circuit which carries at most one or two amperes.

Converter Bulbs.—There are very few new fundamental features or conditions introduced into the mercury vapor apparatus in its use as a converter. One characteristic, however, deserves mention; there is a tendency, under certain conditions, for the negative electrode resistance or a positive electrode to fail, which causes current to flow from some other positive directly to the positive in question, causing practically a direct short-circuit on the system. By proper design this tendency can be controlled very effectively.

The chief feature of interest of the converter is in the new electrical relation introduced into the receiving and supply circuits by the introduction of the converter. Before discussing this relation, however, it will be well to say a few words on the bulb itself. The heat represented by the 14 volts lost in the vacuum, times the current actually flowing, must be dissipated by the bulb. Artificial cooling means may be used, such as fans, immersion in oil, water, etc. Furthermore, a certain portion of this heat is dissipated as radiant energy from the positive electrodes when these are made of solid material.

Although it is possible to operate converter bulbs, utilizing as seals for introducing current one or more platinum wires of the general character of those used for seals in commercial types of lamps, still it is highly desirable on currents over 20 to 25 amperes to have seals for entering the current to the bulb which shall be able to carry momentarily a great deal more current without cracking the glass. Such a seal has been devised by forming platinum into a cup-shaped piece, having a threaded boss on both the inside and the outside of the bottom of the cup. The glass is sealed to the outer edge of the cup, and the electrode stem and external lead respectively are connected to the two threaded bosses. In this form of seal the current does not pass through the metal which is directly sealed to the glass, so that the glass-platinum joint is heated only by heat conduction.

Parallel Running.—Vapor converters can be run in parallel under proper conditions without difficulty. The general condition determining satisfactory paralleling is that the voltage absorbed in each of the paralleled circuits shall increase at least slightly with increase in current, since this insures a division of current between the two circuits. If two devices be used in parallel of such a nature that with increase in current a less voltage is absorbed, such as most mercury vapor lamps, it is evident that the more current one of these devices takes, the more current it tends to take in proportion to the other device on account of its lowered voltage. The bulb of a vapor converter also is usually a device of this character; that is, an increase in current, the temperature remaining constant, causes a decrease in voltage throughout the operating range. In such cases they cannot be connected in parallel directly, since one bulb or the other would instantly take all the current. By the insertion somewhere in the paralleled circuits of a sufficient amount of ohmic or inductive resistance, so that the additional voltage absorbed in the resistance on any increase in current shall be greater than the decrease in voltage in the bulb, satisfactory parallel operation is obtained. Since the voltage change on the bulb would not ordinarily be more than a volt or two, a very slight amount of resistance is sufficient to insure good operation. Obviously, inductance may be substituted for resistance in such parts of the paralleled circuits as carry alternating or intermittent currents.

Since small currents usually require the stored energy of a sustaining coil to maintain them in operation in a converter as well as in a lamp, if a single sustaining coil be placed in the portion of the circuit common to two bulbs connected in parallel, the impulse of the coil, which would otherwise maintain either negative electrode in operation at the time of the momentary tendency to drop out, will be discharged through the other bulb as the easier path, and the first converter will drop out. Consequently, for such types of apparatus it is desirable that each bulb have its own sustaining coil included in the part of the circuit belonging to this bulb alone.

The sustaining coil has the function of supplying energy at low voltage during the zero points of the electromotive force. If one sustaining coil be utilized for two or more bulbs under conditions in which energy is not required for resisting the instantaneous impulses of the negative electrode, it must provide energy for both bulbs. Fortunately, if the coil is powerful enough the energy will be delivered to both bulbs, provided the two circuits are so arranged with resistances or otherwise as to operate in parallel on the generator.

Since a somewhat increased voltage is required in the bulb in starting, to overcome the vapor starting voltage, it is ordinarily more difficult to start one of a number of bulbs connected in parallel after another has been started. For the voltage which is normally lost during running in resistance in other parts of the circuits, is available in a bulb operating singly as an excess starting voltage, while with one of a number of paralleled bulbs operating, since the voltage between the alternating-current and direct-current sides of the other bulbs has been brought to the operating value by the first bulb started, this excess voltage is not available for starting the second bulb.

A number of bulbs designed to operate in parallel can be arranged automatically to cut themselves in and out, either according to the load, or by the accidental dropping out of one of the several bulbs in operation. For this purpose the automatic tilting and starting arrangements used with single bulbs can be controlled by series magnets in the load circuit or in the individual bulb circuits.

Ratio.—The "ratio" of a vapor converter is a rather uncertain term, but may be determined in any given cases as follows:

Any single-phase vapor converter operated from a three-wire source, or a transformer with a middle point, is practically equivalent, as far as the direct-current circuit is concerned, to the application of the original alternating-current to the direct-current circuit (including the sustaining coil) with the negative supply alternations reversed. This gives a pulsating voltage, the pulsations being of sine form and running to zero for one instant twice every cycle. The choke-coil smooths out the current pulsations more or less according to its power and the character of the direct-current load. The smoothing action is much greater with a load of ohmic resistance than with a storage battery or motor or other consumption device having a constant potential feature. The direct-current voltage is measured ordinarily by a direct-current voltmeter which gives the average reading, not the effective reading, of the pulsating voltage, while the alternating-current voltage is measured by an alternating-current voltmeter which measures effective values; so that the direct-current instrument will show a reading on the same voltage of approximately nine-tenths that of the alternating-current instrument. This difference appears in the ratio of the vapor converter. Since only one-half of the voltage across the positives is operative at any one time, we have in addition the factor ½ between the voltage across the positives and that in the direct-current supply, so that the voltage on the direct-current side, measured by direct-current voltmeter, will be 0.45 of the voltage across the positives in the condition assumed. In this case the voltage on the bulb and all auxiliary losses must be included in the direct-current load. If an alternating-current instrument be used for measuring the direct-current voltage a somewhat higher ratio (0.50 as a maximum) may be obtained, according to the degree of smoothing accomplished in the choke-coil. The smoother the direct current the lower the ratio. Both alternating-current and direct-current instruments will, of course, read the same on a perfectly steady current, such as would result from an infinitely powerful sustaining coil. A wattmeter on a vapor converter, having a resistance load, will show a power-factor less than unity, under most conditions, and yet there is no lag between the zero point of the current

and the zero electromotive force of the supply. This condition results from a distortion of the current wave resulting from the action of the sustaining coil in the direct-current circuit. The power-factor appears less than unity, since the distortion of the current is equivalent to the addition of higher harmonics which being of a different periodicity from the supply can deliver no real energy while still increasing the effective value of the current. These matters are of great interest and practical importance, but would require too much space for further discussion in this paper.

The ratio of the current in the direct-current load to that in the supply circuit is one-half, except for the variations of instrument indications which result from wave-form distortion, and except for the fact that a certain amount of current is supplied to the load by the sustaining coil at periods of low supply electromotive force, which current does not appear in the supply. It is here assumed that the supply is connected directly across the positives.

Current Control.—Where a direct current of constant potential is desired through the use of a vapor converter, this can be properly accomplished by the direct connection of the work circuit through the converter and a sustaining coil, and the constancy of the direct-current potential will be directly equal to that of the alternating-current supply, since though 15 volts are absorbed by the bulb this value does not increase with increase of current.

In cases where it is desired that the direct-current potential shall be continuous, even when no direct current is drawn, it is evident that with single-phase converters auxiliary means must be supplied to keep the bulb in operation. This is accomplished in a number of ways, for instance, by a shunt which is kept always running, or by providing a separate circuit with a separate source of electromotive force passing current through the bulb from separate positive electrodes and utilizing the same negative as the main circuit.

Where regulation of the current is desired, as in operating storage batteries, it is not sufficient to provide a constant potential alternating-current supply, but some means equivalent to the adjustable resistance ordinarily used in direct-current systems for this purpose is necessary. This can be easily accomplished by the introduction of inductance, preferably adjustable in the main positives or in the supply. Since the voltage taken up by the resistance or inductance is fixed as the difference between the supply voltage and the direct-current potential by changing the ohmic value of this "resistance" or backing, we, of course, alter the current strength.

Physical Explanations of Short Circuits in Converters.—The general assumption or hypothesis upon which the reactions of the vapor apparatus are explained in the early part of this paper needs some amplification in connection with the converter. There is a tendency for the negative electrode resistance to fail in one of the positive electrodes in some types of bulbs during the time that it is impressed with a negative voltage, thus causing a short-circuiting of the supply. One way to eliminate this difficulty is to interpose around the electrode a screen to obstruct a direct line from the non-operative positive electrode to the negative electrode or to the bath of the current between the negative and the other positive electrodes. Furthermore, this tendency is very much reduced by the elimination of the last traces of foreign gases or vapors originally in the bulb. This action can be easily explained if we assume, as already described in connection with the arc in air, that positive ions accumulating on the surface of a positive electrode under electric strain will cause the negative electrode starting resistance to fail.

Thus we may assume that a part or the whole of the residual gas (as distinguishable from mercury vapor) remaining within the bulb becomes ionized by the operation of the converter. Then the electrons will be attracted to the operating positive electrode, while the positive ions will be attracted to the other positive electrode since that is at a lower potential than the negative, where they may be capable of initiating a short-circuit. The introduction of the screen above mentioned will evidently prevent the positive ions from reaching the negatively charged positive electrode since they are attracted thereto in straight lines and will be held by the force of attraction against the surface of the screen. If there be an excessive quantity of ions, however, some of them may find their way around the shield, especially in view of repulsion by those initially accumulated on the screen, and finally cause a short-circuit.

RECENT PROGRESS IN METALLURGY.*

By PROF. A. E. OUTERBRIDGE.

IN reviewing the progress made in metallurgy during the past twelve months it is desirable not only to take cognizance of the notable achievements in practical applications of science to utilitarian purposes, but also of the new theories regarding the nature of matter.

During the year past the production of all metals has been phenomenally large. The rise and fall in the production of pig iron has long been regarded as a sort of barometer of business prosperity for allied lines of industry, and all previous records fade into insignificance when compared with those of the year ending June 30th last, for in that period of time the production of pig iron in the United States amounted to no less than 24,432,106 tons. The production in the State of Pennsylvania alone was, in 1905, 10,579,127 tons, or about two million tons more than the total production in the United States in 1896. Those who are interested in such matters will, no doubt, remember the astonishment that was caused when the statistics of production of pig iron in 1898 were published, showing a total of 11,773,394 tons, or nearly one million tons a month. Since that time we have advanced by leaps and bounds until now we are actually producing over two million tons a month of pig iron.

An interesting improvement in the pig iron industry, to wit, the Gayley dry-air blast process, is worth noticing. The process has proved itself to be highly economical and will doubtless be largely introduced. During the year 1905 there was produced 276,000 tons of pig iron by this method, and several large plants are now in course of construction.

The per capita consumption of pig iron in this country has risen to 620 pounds, as compared with 68 pounds as the average consumption of the total production in the world in 1905.

The remarkable activity here noted is not confined to iron, but extends to all metals, gold, copper, aluminium, etc. In 1880 the production of copper in the United States amounted to about 25,000 tons, or about one-sixth of the world's output. In 1905 the production was 397,909 tons, or about one-half of the world's output.

There is an unlimited demand for copper, just as there is for gold (due, however, to a different reason), and this has caused the price of copper to rise greatly, notwithstanding the fact that the cost of refining has been much reduced through the modern electrolytic methods. It is estimated that the aggregate profits of the producing industry in twenty-five years have amounted to the enormous sum of $675,000,000 on a total production of 9,000,000 tons. By far the largest proportion of these profits have been made within ten years.

The speaker next called attention to the extraordinary increase in production of gold all over the world in recent years, but more especially in this country. A graphic chart showed an almost perpendicular line. Here again the modern methods of economical production are in evidence; gold ores are being profitably worked to-day that were considered quite worthless a few years ago.

The metal aluminium, once called "the metal of the future," is now entitled to a high place in the list of economic metals of to-day, the production having increased from a few pounds ten years ago to about 5,000 tons in 1905. Owing to the discovery of the electrolytic method of refining the cost of the pure metal has declined from $8 to less than 50 cents a pound.

Statistics were given to show that the remarkable increase in production of metals in 1905, as compared with previous years, was not confined to the United States, but was world wide. Canada, for example, showed an increase of no less than 171 per cent in output of all kinds of steel ingots and castings in 1905 as compared with 1904, and an increase of more than 72 per cent in crude pig iron.

The production of pig iron in Great Britain in 1905 was the largest in the history of the United Kingdom, being 9,592,737 tons, as compared with 8,562,658 tons in 1904.

The increase in output of Bessemer steel ingots in the same period was shown to be about in the same proportion and of open-hearth steel ingots in larger proportion.

In Germany production is recorded in metric tons, and there was a considerable increase in output of pig iron, steel ingots, and castings in 1905 as compared with the previous year.

In France the increase in output was comparatively small, and the same is probably true with respect to Russia, Spain, and Italy, though accurate statistics for these countries are not yet available.

Reference was made to the great progress made in recent years in recovering so-called waste products in various metallurgical operations. One of the most promising of these is the prospective utilization of vast accumulations of blast furnace slag in the manufacture of high-grade cement. The possibility of this has been talked of for years, for the reason that slag contains a great deal of lime, a material used in making cement, but, unfortunately, the sulphur in the slag is a deleterious element. Recently the United Steel Corporation has perfected a process, it is said, for eliminating sulphur and making fine cement from slag.

When we realize that the demand for cement is increasing every year, and has now reached enormous proportions (the output of cement in 1905 in this country exceeded forty million barrels), we can appreciate the importance of this new undertaking. It is stated that a subsidiary company has been very recently formed under the title of the Universal Portland Cement Company to manufacture cement from blast furnace slag.

The use of ferro-alloys in the manufacture of "high-speed" steel for cutting tools has made great progress during the past year and has been extended in various directions with remarkable results. Large and costly milling cutters are now being made of this steel, as well as planer and lathe tools and drills. Improved methods of hardening and tempering this kind of steel have also been devised.

The use of ferro-alloys in the foundry is likewise extending. The simple method first described in the speaker's address given before the metallurgical section of the Institute a year ago for softening iron for castings to any desired degree has been continued, with exceedingly beneficial results, in daily practice.

The speed of turning pulleys has been largely increased and the time required to complete the machine work upon them has been reduced, and in other light castings as well. In addition to the material improvement in the strength of the metal by this treatment, there is a decided decrease in shrinkage, so that some castings of irregular shape which are difficult to make without cracking in cooling owing to unequal strains are now made without this tendency by this process. Other advantages accruing from the addition of a very small amount of high-grade ferro-silicon (containing about 50 per cent of silicon) have been observed. Among these may be mentioned the cleaning action upon the molten metal which the alloy effects by its deoxidizing influence. Singularly also it is found that commercially pure silicon does not produce these results, neither does the ordinary grade of ferro-silicon, containing about 20 per cent of silicon.

In the case of pure silicon the specific gravity of the material is too low and its melting point too high to permit it to become incorporated with the molten iron in the ladle, in the other case the proportion of silicon is too low to permit a sufficient amount to be dissolved in the iron to produce a radical change in its quality without causing dull iron in the ladle.

There is no doubt that when the merits, simplicity, certainty of action and other advantages of this process of treating molten iron in the ladle are better known it will come into very extensive use, for it enables the founder to modify the character of his iron to suit individual castings, a matter of considerable importance and value. This is accomplished without expense, for the cost of adding silicon to the iron in this manner is actually less than by the usual method of adding an equal amount of silicon to iron in the form of pig iron comparatively high in silicon added in the cupola. For example, pig iron containing 6 per cent of silicon costs at the present time, let us say, $20 per ton, and we may estimate for comparative purposes $3.33 per unit of silicon; ferro-silicon containing 50 per cent silicon costs at the present time in powdered form $100 per ton, or $2 per unit of silicon on the same basis of calculation.

Furthermore, there is no loss of silicon when added in the ladle as there is when melted in the cupola, and this partly accounts for the fact that a given quantity of silicon, when added in the ladle, is much more effective as a softener than the same quantity charged into the cupola. Silicon added in the cupola always weakens the iron, while silicon added in the ladle always strengthens it.

The output of gold has quadrupled in the past twenty years, and stands, as regards its rate of development, above all other metallurgical industries, iron alone excepted. In a recent résumé of two papers by M. de Launay, an eminent French mining engineer, and professor at the Ecole Supérieure des Mines, published in the Revue Générale des Sciences, the Engineering Magazine says: "The enormous increase in the rate of production of gold is one of the remarkable industrial and economic phenomena of the present time. The curves representing the production of other metals have shown upward tendency, more or less marked, but the line showing the gold production of the world shows such a remarkable upward tendency that at times it almost approaches the vertical. When the curve is separated into its three components, representing respectively the three principal sources, the Transvaal, the United States, and Australia, it is seen that there is a marked similarity between them, interrupted only by the break due to the war in Africa. The figures for the year 1905 given by M. de Launay, in francs, are: Transvaal, 524 millions; Australia, 432 millions; the United States, 436 millions; a total of 1,392 million francs, or about 278 million dollars. These three countries produce 72 per cent of the world's total, which reaches 1,908 millions of francs. . . . It is largely because of the improved process of extraction that the production of gold has increased at the rates already given, since it is by the wholesale application of modern methods that the lowest grade deposits can be commercially worked. Thus, in a large and accessible mine it is assumed, on an average, that the material can be treated for about 12 francs per ton. Very often, however, the cost reaches double this figure, according to location and operative difficulties. In the great workings in Dakota, on the contrary, the cost has fallen as low as 2.10 francs per ton, and at the Alaska Treadwell mine to the minimum of 1.12 francs."

It is interesting to recall the fact that many years ago the assayers of the mints found that gold was uniformly distributed in very minute division in the bed of clay underlying the city of Philadelphia, and they made the astounding statement in a paper published in the Proceedings of the American Philosophical Society that there was more gold underlying the streets of the city than had been taken at that time from California and Australia combined. There was enough gold (according to their calculations) in each brick, if hammered into leaf, to make a sheet of gold two inches square and about one-three-hundred-thousandth of an inch thick. It was, of course, stated that the cost of extracting the gold would be far in excess of its value, but modern methods of refining low-grade ores had not been discovered at that time, and it may come to pass that the alluvial gold in the clay may yet have a market value. This, however, is a mere speculation at present. Certain it is that the vast increase in production of gold in modern times is due to the economical methods of reclaiming the gold from lean ores that had no value whatever at the time this interesting paper was published.

* Paper read before the Franklin Institute.

The increase in production of copper in the United States in recent years can be truly described as astounding, the output having risen from 25,000 tons in 1880 to 413,070 tons in 1905.

In the former year we produced about one-sixth of the world's output and in 1905 more than one-half. The enormous increase in production has been stimulated largely by the increased demand since the development of electric lighting and electric power. The price of copper has risen coincidently with increase in production, notwithstanding the fact that modern methods have greatly reduced the cost of refining copper.

In 1880 the electrolytic method of refining was in its infancy; there was, in fact, no refining by this method recorded in this country in that year, while in 1905 the output of electrolytically refined copper in the United States was 304,000 tons, as compared with 46,000 tons in Europe.

The electrolytic process of refining copper is one of extreme simplicity; it depends primarily upon the passage of an electric current between two plates of copper suspended in a tank containing copper sulphate in solution. As only the copper in the crude metal can act as a carrier of the current the impurities are left behind, and pure copper alone is deposited on the plate of metal by which the current leaves the vat.

The impurities frequently consist of gold and silver in sufficient quantity to more than pay all cost of refining the copper by this process.

A NEW RESPIRATORY APPARATUS FOR USE IN FIRES AND MINES.

By the English Correspondent of SCIENTIFIC AMERICAN.

SOME interesting experiments have been carried out in London with the Chapin-Sherman respiratory apparatus, or smoke helmet, devised by Messrs. Chapin and Sherman, of San Francisco. The experiments have been carried out before officials representing the Fire and Salvage departments, as well as the Home Office and Admiralty departments of the government.

The Chapin-Sherman apparatus possesses many interesting and distinctive features. In the majority of such appliances the fundamental basis of the machine is the preparation of the requisite air for breathing by chemical means. The air for inhaling is either generated within the appliance itself, or the outer contaminated air before reaching the mouth is scrubbed by passage through a cylinder containing chemicals, whereby the impurities in the atmosphere are arrested before reaching the mouth. Such systems though highly efficient in skilled hands have many disadvantages. In the first place, their mechanism is necessarily somewhat intricate and delicate, requiring careful handling on the part of the operator, while on the other hand it is imperative that the chemical agents employed should be absolutely fresh, so as to fulfill their desired functions to satisfaction. Under these circumstances they are scarcely suitable for the average miner or worker, seeing that his knowledge of chemicals and their use is perforcedly limited.

In the case of the respiratory apparatus designed by Messrs. Chapin and Sherman no chemicals whatever are employed, the operator being supplied simply with a reserve of pure air under compression. The apparatus is very simple both in design and operation, possessing few integral parts, so that the liability of its becoming deranged is a remote contingency. At the same time it is so efficient that by its aid a man can penetrate the densest smoke or the most poisonous and overpowering fumes and gases with perfect safety, while another distinct advantage it possesses is that it can be brought into operation at a moment's notice, thereby avoiding any preliminary preparations.

THE UTMOST FREEDOM FOR MOVING THE ARMS IS ALLOWED.

The air supply is contained in three cylinders strapped to the back, so that the arms have perfectly free action. These cylinders are made of copper and capable of withstanding a water pressure equivalent to 500 pounds per square inch. Two of these cylinders are of identical dimensions, and carry the normal supply of air, while the third is somewhat smaller and acts as an emergency supply for use when the two larger cylinders have become exhausted. The two larger cylinders are charged with air under 300 pounds pressure, and this is adequate to last a man forty minutes, which in the majority of cases is a longer period than will be required. The emergency cylinder contains sufficient air for ten minutes. When the operator finds that the supply in his larger cylinders has become exhausted, this fact warns him that it is time for him to return to the outer air to receive a fresh charge, and the contents of the emergency cylinder enables him to retrace his footsteps and emerge from the danger area without fear of being overcome himself. This is a valuable adjunct, since on more than one occasion a man, although equipped with a respiratory apparatus, has lost his life when working in a danger zone through his air supply giving out without the slightest warning, and he has been too deeply engaged in his work to observe that his supply of air is running short.

SIDE VIEW OF THE RESPIRATORY APPARATUS.

The air from the storage cylinders is carried through a flexible rubber tube to the smoke helmet. This completely envelops the head, being tied around the neck. The cap is made of oiled silk or cloth perfectly airtight and provided with an outer protecting cover of fire-proofed linen. There are two lookouts before the eyes of large size with the frames made of aluminium alloy. These frames are secured to the material of the cap by means of screws, the glass or mica pieces, whichever transparent material is used, being held into position in the frames by outer screwed flanges. By this means the closures can be quickly replaced in the case of breakage.

In front of the mouth is fitted a special valve of simple design, and which at the same time prevents the entrance of smoke or fumes into the interior of the cap By raising the valve from its seating and giving the controlling knob a quarter of a turn in either direction, the valve is opened and the wearer can then inhale the outer atmosphere, while a similar reverse movement of the knob instantly causes the valve to resume its seating, cutting off communication with the outer air. This ingenious device is of great utility to the operator, since when working in a dangerous zone, where there are possible intervals of pure air, the man can immediately avail himself of this advantage by inhaling the outer atmosphere, immediately reverting to the cylinder supply when foul air is encountered, thereby husbanding the reserve carried upon his back.

The air supply from the cylinders is controlled by means of a needle valve. Each of the two larger cylinders has the valves operated by a small hand wheel, while that of the emergency cylinder is actuated by a small crossbar, thereby rendering it impossible for the wearer to turn on the reserve supply by mistake. The operator is able to regulate his supply as desired, but cannot turn on more than the pressure that normally prevails in the outer atmosphere, so that there is no risk of the wearer experiencing any ill effects through inhaling the air at too great a pressure. The valves and connections under pressure are made of phosphor-bronze, the valve stems being made of Tobin bronze, so that the danger of corrosion and subsequent leakage is completely removed.

The air reservoirs are firmly secured to the back of the operator by leather straps having broad shoulder pieces. These straps cross over the chest, and by means of hooks and chains fastened to the bottom of the cylinders any desired adjustment may be obtained, so that the appliance can be worn by a large or small man with equal facility. The total weight of the complete apparatus is only twenty pounds, which being well distributed over the body is scarcely appreciated by the wearer. Owing to the simplicity of attachment, it can be donned by a man without any assistance in twenty seconds.

The cylinders can be discharged or recharged either separately or simultaneously as desired. In charging, however, which is carried out by a Kellogg compound air-pump, it is advisable to open all the valves so as to insure an even pressure. Each valve is further fitted with an adjustable stop, so that any unnecessary opening of the valves and attendant waste of air is overcome. The small emergency cylinder, though normally provided with a ten minutes' supply to enable the wearer to escape from the danger zone when the main supply is exhausted, can be adapted to larger reserve supplies if desired, according to the exigencies of the case, but the period allowed has been found to be invariably sufficient for the purpose.

The apparatus can be utilized for all purposes with equal success, be it either for penetration in a burning building where dense clouds of smoke prevent the firemen making an entry in the ordinary manner, the hold of a vessel, deep wells at the bottom of which large masses of poisonous air invariably accumulate, or n..nes filled with suffocating gases. No matter how dense the clouds of fumes or smoke may be, there is no possibility of the wearer of the apparatus being affected thereby. This fact was conclusively demonstrated at the severe tests imposed upon it at the headquarters of the London Salvage Corps before the numerous officials of the Fire Brigade, Board of Trade, medical and health officers, and Prof. Vivian Lewes, Cantor lecturer on fire chemistry, and other interested authorities. A fireman who had never before seen the apparatus was locked in an apartment in which was burning straw and sulphur, which emitted the densest clouds of smoke and fumes. Though immersed therein for fifteen minutes, the fireman experienced no difficulty in the manipulation of the appliance, nor did the slightest traces of the overpowering fumes penetrate the smoke cap, though an ordinary man could not have existed in the poisonous atmosphere for thirty seconds without being overcome. The authorities expressed themselves completely satisfied with the efficiency of the apparatus. At the present moment the British government, impressed by the magnitude of the mining disaster in France, and the urgent necessity for some means of succoring the men overpowered by the gases in the subterranean workings, have appointed a special commission to investigate the various apparatus for enabling rescuing parties to penetrate the danger areas. Some of these officials have already witnessed the experiments with the Chapin-Sherman system, and have shown great interest in the matter. The authorities controlling the sewerage department of London have also realized its possibilities in enabling men to carry on their tasks in the sewers without danger from the volumes of sewer gases, for which phases of operations the apparatus is eminently adapted and more advantageous than the diver's apparatus now utilized, and which are so heavy and cumbersome while the range of action is necessarily limited, owing to the connecting pipe through which the air is pumped.

SIGNIFICANCE OF "THROWING THE SHOE."*

THROWING the old shoe was not always confined to weddings, though the custom nowadays has come to be associated entirely with the going away of bridal couples. Authorities differ concerning the origin of the practice as well as of the exact meaning attached to it, but there seems to be a general opinion that it has to do with some very ancient ceremony or rite in connection with the transfer of property—woman being regarded as such among the nations where the custom of such a ceremony is first found.

There is also the possibility of its referring to the

* The Scrap Book.

time when the bridegroom carried off the bride by force, though this seems less likely.

It was in the sense of confirming a sale or exchange that the Jews understood the removal and giving of a shoe or sandal. When the kinsman of Boaz consented to waive his claim upon the parcel of land which Naomi would sell, in favor of Boaz, he "drew off his shoe," for "this was a testimony in Israel."

In a different sense the removal of a shoe marks the winding up of negotiations among the laws and ordinances given in the book of Deuteronomy, where the widow who is refused marriage by her husband's surviving brother is directed to "come unto him in the presence of the elders, and loose his shoe from off his foot," thus asserting her independence and heaping upon him the blame for failure to comply with the law.

When the Emperor Vladimir proposed marriage to the daughter of Reginald, she refused him with the words:

"I will not take off my shoe to the son of a slave."

In Anglo-Saxon marriages the bride's father delivered her shoe to the bridegroom, who touched her on the head with it in token of his authority.

The idea of luck is the principal thought associated with it always in these later times—especially luck in making journeys.

Ben Jonson wrote—

Hurl after me a shoe,
I'll be merry whatever I'll do,

and old Heywood says—

And home again hitherward quick as a bee,
Now for good luck, cast an old shoe at me;

while Tennyson ("Lyrical Monologue") tells us—

For this thou shalt from all things seek,
Marrow of mirth and laughter,
And wheresoe'er thou move, good luck
Shall throw her old shoe after.

Undoubtedly it is the remnant of something which came from the Egyptians or some other ancient nation with which the Jews came in contact, though investigation shows that it was never confined to any one race.

There are some interesting points in regard to the practice which have usually been overlooked in treating the subject, for example, the priests and worshipers at the shrines of the Roman Cybele, the Grecian Ops, the Canaanitish Ashtaroth, and the Egyptian Isis were compelled to remove their sandals.

The shoes and sandals of the Greeks, Romans, Egyptians, and Jews were ornamented with horns, crescents, and other representations of the moon, while at marriage ceremonies the custom of casting the shoe was, and is now, combined with the throwing of flowers and various kinds of grain. These symbols and offerings seem to indicate the propitiation of a god, probably the deity who presides over productiveness.

THE MUSEUM OF ACCIDENT PREVENTION.

THE new French Museum of Prevention of Labor Accidents and of Industrial Hygiene in the Vaucanson gallery of the Conservatoire des Arts et Metiers, is not so much a permanent museum as an exhibition that can be modified in measure as new inventions and improvements take place. New apparatus more satisfactory in every respect and found superior by trial will constantly replace former ones, which will be gradually relegated to the rank of curiosities or antiquities. Similar museums are already to be found in Vienna, Amsterdam, Munich, and Charlottenburg. The one in the latter city cost $2,600,000 and has an endowment of $10,000 a year.

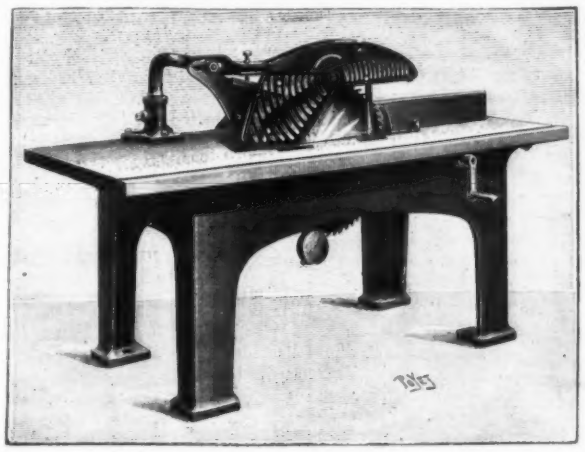


FIG. 1—CIRCULAR SAW.

The prevention of accidents has become a true science, to which numerous associations have devoted themselves. The first of these was founded in 1867 by Engel Dolfus, a manufacturer of Mulhaus and a generous man of means whose bust occupies a place of honor in the French museum.

The establishment of the new museum is due to the Association of the Manufacturers of France, which obtained a decree for its creation on September 24, 1904. It is established solely by private subscription and gifts. Its nucleus was the collection of models brought together by the above-named association as long ago as 1893. Its object, which is essentially philanthropic and social, is to make known to employers through what apparatus, what precautions, and what means they can protect their workmen—their manual laborers—against the risks of all kinds to which they are exposed, such as dangers from machine tools, transmissions, electricity, etc.

In the Museum of Accident Prevention, employers will learn how to safeguard and care for their workmen, while the latter will receive instruction in those matters pertaining to prudence and hygiene with which they are too little acquainted. It is here that workmen will learn, by means of models or drawings, to know and how to manage the most improved protective apparatus.

The hygiene of the workshop, which seeks to render the large modern factories salutary and agreeable, aims at the high ideal of increasing the well-being and the health of the workmen; and the museum of industrial hygiene details all the means for attaining that object. At its inception it is divided into three halls. A mention of but a few of the objects exhibited therein and the accompanying figures will suffice to render its rôle understood.

In the first hall we noticed upon a cursory examination a series of different machines provided with protective devices painted red in order to make them more conspicuous, such as gear coverings, a Lomont protected vertical lathe, a centrifugal cream separator with a cover for the dangerous parts, circular saws and punching machines with an arrangement to prevent the operators from cutting their fingers, etc.

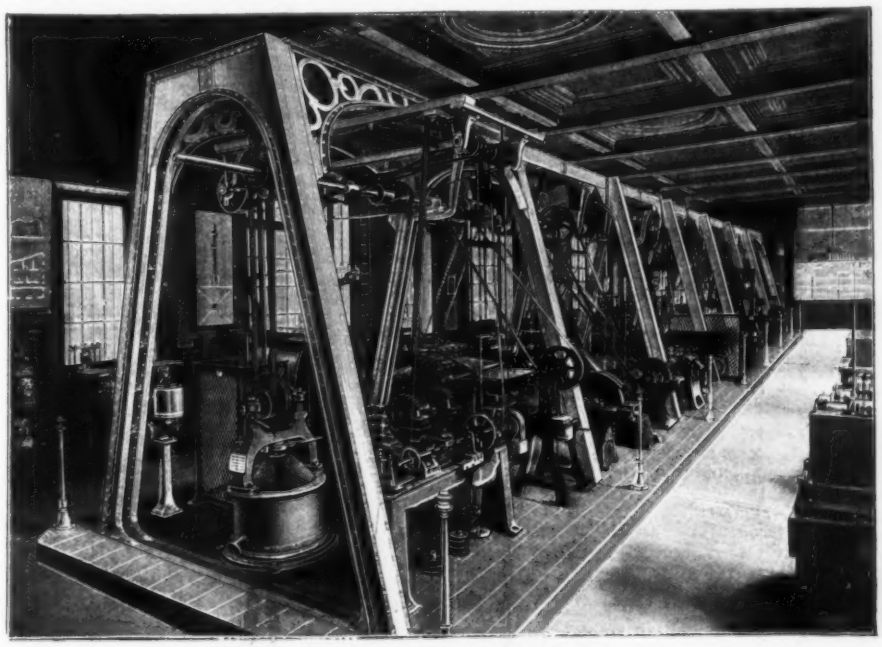


FIG. 4.—GENERAL VIEW OF THE HALL.

The second hall shows litters and stretchers for the carriage of the wounded, and especially some very curious and efficient mecanotherapeutic apparatus for the reduction of fractures, etc.

In the third hall we find pneumatic shock-absorbers for the carriage of the wounded, safety arrangements for roofs, Chesneau grisoumetric lamps, etc. As for hygiene, owners of manufactories will have only to choose from among the various purifying filters of

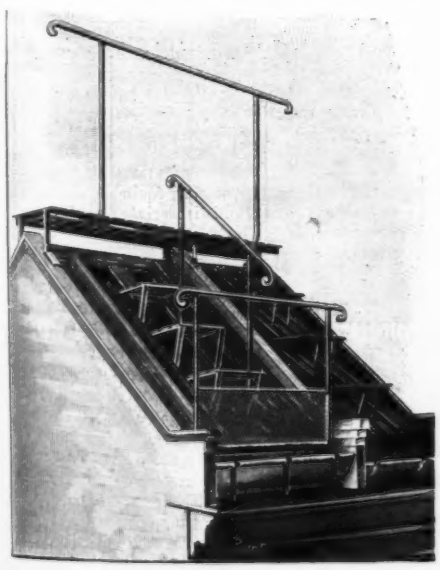


FIG. 2.—SAFETY DEVICE FOR A ROOF.

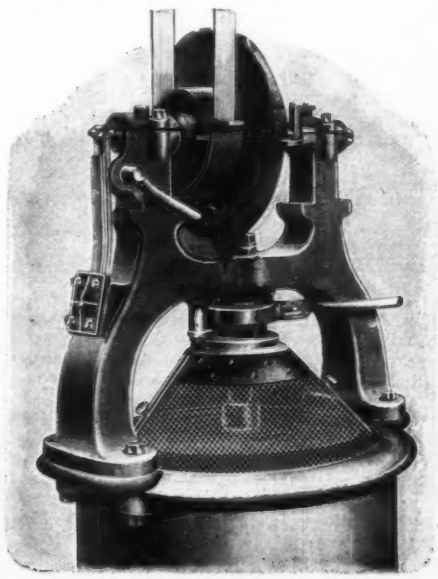


FIG. 3.—HYDRO-EXTRACTOR.

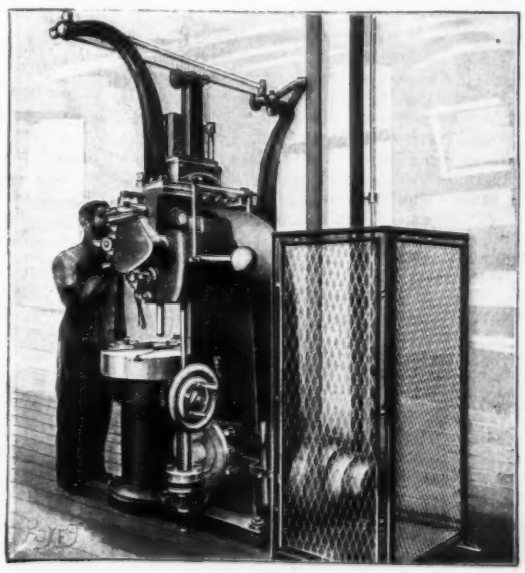


FIG. 5.—VERTICAL LATHE.

Lutece, Grandjean, Chamberland, etc., the shower baths, washstands, and other like accessories. The suppression of vapor in dyeworks and the aspiration of dust and particles of cotton from spinning mills are problems solved by numerous ingenious mechanisms or processes. As a first-class object lesson, the Museum of Accident Prevention is certainly destined to constitute one of the most useful sections of our great establishment for industrial instruction.—Translated from La Nature for the SCIENTIFIC AMERICAN SUPPLEMENT.

THE BALD EAGLE OF THE UNITED STATES.*

THE bald eagle, otherwise variously called white-headed eagle, white-headed sea eagle, and bird of Washington, is of particular interest to Americans as the national emblem of the United States, to which dignity it was elevated on June 20, 1782. The name "bald" eagle, by which the species is almost universally known, originated from the white head and the erroneous impression of baldness it gives at a distance.

This bird measures about 3 or 3½ feet in length, from 6 to 8 feet in extent of wings, and weighs from 6 to 12 pounds. When fully adult its color is dark brown, with white head, neck, and tail, yellow bill, eyes, and feet. At least three or four years are required for the assumption of this plumage, younger birds being entirely brownish or blackish.

The bald eagle inhabits nearly the whole of North America, from northern Mexico and Florida north to Ungava and the Anderson River, west to the mainland of Alaska, the Aleutian Islands, and the Commander Islands, Kamchatka.†

Over much of its range, particularly in the more thickly settled parts of the United States, the bald eagle is by no means common during the breeding season; but in sections of Florida, on the Aleutian Islands, the coast of southern Alaska, British Columbia, and Washington it seems to be more numerous than anywhere else. From the more northern regions, particularly the interior of Alaska and of northern Canada, it withdraws for the winter when the lakes and rivers freeze; but elsewhere it seems to have no regular or well-defined migration, although during the cold season it wanders more or less, apparently influenced largely by the food supply, since it is easily able to withstand the rigor of even an Arctic climate. It is more maritime and fluvicoline than the golden eagle, preferring the neighborhood of the seacoast, lakes, and larger streams, and it is seldom really common at a distance from them. It inhabits, however, all kinds of country so long as the main requisite—plenty of water—is there, and in mountains or on plains, in heavy forests or along barren shores it finds a congenial abode.

Under most circumstances wary and difficult of approach, with an eye open for danger and giving suspected things a wide berth, this eagle, nevertheless, where not molested, is often surprisingly tame and unsuspicious. Unprovoked it rarely attacks man, although such instances have been reported. It prefers trees for watching and roosting, but in spring sometimes descends to ride the cakes of ice in the river, apparently looking for fish. Though not a gregarious species, it may at times be seen in companies of as many as ten or even fifteen individuals. It is evidently not lacking in conjugal affection, and the first mating results in an alliance, defensive and offensive, that is believed to last as long as both survive; but when one of a pair dies, the other, male or female, soon secures another partner that at once assumes the responsibilities of the interrupted household. The notes of this eagle are few, usually produced in a loud, harsh scream, but heard at a distance they lose much of their disagreeable sound. The flight is powerful, capable of being indefinitely sustained, and is accomplished now by steady wing-beats, now by soaring either on a level course or in great ascending circles as is the habit of most large birds of prey. The bird occasionally makes a plunge from a great height—a marvelous feat, performed with such velocity that the eye can scarcely follow the descent. In strength the bald eagle is hardly less remarkable than in power of flight, and it has been known to carry for five miles a lamb of weight fully equal to its own. It can readily be kept in confinement, for it will thrive on any kind of meat or fish; and it sometimes even develops no little attachment for its owner.

This species breeds throughout its range wherever suitable places exist, and it has been known to lay and hatch eggs in confinement. In the southern part of the United States, from Florida to Texas, it breeds very early, depositing its eggs usually during the first half of December, exceptionally about the 1st of November, occasionally in January or February; in the Middle States and in California it lays in February or March, and to the northward correspondingly later—about the middle of April in southern Alaska, sometimes in May, or even in June, in the Arctic regions.

The nest is located nearly always in the vicinity of a stream or body of water, often along the seacoast. The favorite site is the top of a tall tree, in the South often a pine, frequently a hundred feet or more from the ground. Where there are no trees a rock or a niche in a cliff serves the purpose, while along the coast of Texas nests have been found even on the ground of low islands.

The same nest is occupied year after year, and annually repaired or augmented until it becomes an immense structure, 5, 6, or even 8 feet high and as much in diameter, containing fully a cartload or two of material. It usually forms a strong platform with only a slight depression in the center, and easily sustains the weight of a man; but when built on the ground it occasionally consists merely of a few sticks and a little rubbish. The usual material is sticks of all sizes up to fully 3 inches in diameter and 5 feet in length, weeds, vines, grass, moss, and pieces of turf, with more or less lining of twigs, grass, straw, hay, moss, lichens, leaves, and seaweed.

The eggs are dull white and generally two, unusually one or three, rarely four in number. They are deposited at intervals of two to four days, and incubation, in which both male and female take part, lasts about thirty to thirty-six days. The nestlings are at first covered with a whitish, then a grayish, down, which in time gives place to the firmer dark brown feathers of the first complete plumage. They remain a long time in the nest, probably at least three months, during which period they are lavishly supplied with food by their parents.

The old birds commonly make but little demonstration when the nest is approached or even closely examined, though in a few instances they have been known viciously to attack the intruder. Only one brood is reared, and if eggs or young be destroyed no further attempt to rear young is made the same season. Often the old birds, particularly in the South, frequent the nest during much of the year, using it as a kind of general rendezvous.

The bald eagle lives partly after the manner of vultures, gorging itself to repletion when opportunity offers, then perhaps obliged to fast for days. Lack of food even for a considerable period is apparently no serious inconvenience, since Mr. George A. Boardman once kept an individual without food for thirty-two days. The indigestible portions of its food are ultimately disgorged in the shape of pellets that resemble those of owls. One of these pellets, found by Mr. Edward A. Preble, of the Biological Survey, in a nest at Mount Vernon, Va., some years ago, was almost round, about 1⅝ inches in diameter, and composed entirely of the feathers of poultry, together with some mammal hair. The young of this species appear to be fed on the same kinds of food as are eaten by the adults.

Fish seems to be the principal food of the bald eagle, and when obtainable is often preferred to anything else. The dead fish found along the shores of sea or lake or river, those that the eagle catches by its own efforts, and those of which it robs the osprey are alike acceptable. In many places it obtains a good share of its food from the dead fish cast up by the waves. Mr. William Brewster mentions that in 1879 it was abundant about Lake Umbagog, Maine, drawn thither to feed on the suckers that in great numbers had died and been left on the marshes and flats by the receding water, while Audubon relates that it was frequently seen to pick up catfish heads which were floating on the St. Johns River, Florida. Mr. C. P. Streater found it common at Sauk, Wash., in September, 1891, feeding on the dead salmon (*Oncorhynchus* sp.) along the shore; and similar observations have been made by others on the Columbia and other rivers of the Pacific coast. Mr. J. C. Hughes records* that along the lower Fraser River in British Columbia he has found it feeding extensively on the oolachans, or eulachons (*Thalcichthys pacificus*), a small fish that is abundant there; and so numerous does the eagle become at times when the fish are running that Mr. Hughes has on occasion counted as many as a thousand in a distance of three miles.

But the bald eagle not infrequently goes fishing for itself, using a variety of methods, according to circumstances. Sometimes from its perch on the summit of a dead tree it launches downward and, falling like a stone, seizes its prey; sometimes it hunts on the wing, much like an osprey, and when a fish is perceived poises by rapid wing-beats, finally dropping into the water even from a great height, and not infrequently becoming almost completely submerged; then, again, it varies this last method by flying leisurely along near the surface of the water. Audubon mentions that along Perkiomen Creek near Philadelphia, Pa., he saw it on several occasions wading in the shallows and striking at the small fish with its bill; and other observers elsewhere have noted a similar habit. It has been seen scrambling over the ice of a pond, trying to reach the fish below; and Mr. W. L. Dawson, in his "Birds of Ohio," says that at the Licking Reservoir, Ohio, it is reported in winter to watch near the air holes in the ice for the fish that from time to time seek the surface. Mr. J. G. Cooper has seen it catch a flying fish in the air, and the amazing celerity necessary for the performance of such an exploit may readily be imagined.

Although the bald eagle does often fish for itself, it finds a much easier and more congenial task in robbing the mild-mannered osprey of his finny prey. These attacks are of such common occurrence in some localities that they are taken by the osprey usually as a matter of course; but sometimes patience becomes exhausted and a number of ospreys successfully unite to drive away the eagle.

About half of the stomachs of the bald eagle examined in the Biological Survey contained fish, and the following species, mostly additional to those that have already been mentioned, were identified: Fork-tailed catfish (*Ictalurus furcatus*), striped bass (*Roccus lineatus*), goldfish (*Carassius auratus*), eel (*Anguilla chrisypa*), sunfish (*Eupomotis gibbosus*), and shiner (*Notemigonus americanus*).

It is a regrettable fact that, after fish, birds constitute the most important part of the bald eagle's diet and sometimes furnish almost the entire food. The larger species, particularly of waterfowl and game birds, are preferred; song birds appear rarely if ever to be molested. Dead birds, principally waterfowl, whenever available are greedily devoured, as many observations prove. Mr. W. E. C. Todd has recorded that numbers of long-tailed ducks (*Haralda hyemalis*) washed up dead along the shore of Lake Erie are disposed of in this manner. Wounded or crippled birds are eagerly seized, but as the supply of these is of course limited, by far the greater proportion of the eagle's avian prey must perforce be obtained entirely by its own exertions.

In most parts of its range it feeds more largely on waterfowl than on any other kind of birds. In the pursuit of this game the bald eagle employs great strength and skill, to which it frequently adds no small amount of strategy. Geese, brant, and swans, owing apparently to the large size, are favorite food. Mr. Robert Ridgway mentioned that on the main island in Pyramid Lake, Nevada, a pair of bald eagles broke up the nest of a Canada goose (*Branta canadensis*) that had been established on the ground not far from their own. Of the goose and brant hunting habits of the bald eagle at Cobb's Island on the Atlantic shore of Virginia near Cape Charles, Mr. William Brewster, from data furnished him by Mr. Nathan Cobb, gives the following account:*

"In the winter the eagles are much more numerous than at any other time of the year, and my informant has, on several occasions, seen as many as eight at once. At this season the neighboring bays and creeks swarm with wild fowl, and upon these the eagles principally live. He has never known them to capture fish of any kind, although they not unfrequently rob the fish hawk. Geese and brant form their favorite food, and the address displayed in their capture is very remarkable. The poor victim has apparently not the slightest chance for escape. The eagle's flight, ordinarily slow and somewhat heavy, becomes, in the excitement of pursuit, exceedingly swift and graceful, and the fugitive is quickly overtaken. When close upon its quarry, the eagle suddenly sweeps beneath it, and, turning back downward, thrusts its powerful talons up into its breast. A brant or duck is carried off bodily to the nearest marsh or sand-bar, but a Canada goose is too heavy to be thus easily disposed of. The two great birds fall together to the water beneath, where the eagle literally tows his prize along the surface until the shore is reached. In this way one has been known to drag a large goose for nearly half a mile.

"A single bird is usually seized at the first attempt, but Mr. Cobb has seen an eagle repeatedly miss his aim when in the midst of a large flock. The very abundance of opportunities seems to bewilder him, and he thrusts wildly and harmlessly in all directions; but after the crowding masses have become scattered by his onslaught, a separate individual is selected, and quickly overtaken and killed.

"Although the larger and heavier waterfowl are more likely to be attacked, the royal bird seems to find little difficulty in overhauling the swiftest flying ducks. The latter, however, often escape by diving, although in shallow water this recourse sometimes proves of no avail, as the eagle follows their course, and seizes them as they rise near the surface. Under favorable conditions even grebes are sometimes captured.

"In winter shooting the sportsman loses many a wounded goose or brant by the eagles. They seem fully aware of the advantage to be gained by maintaining a close espionage upon the gunner's movements, and a bird that falls at any considerable distance from the stand is often seized and borne away before it can be recovered."

Ducks of various kinds, by reason of abundance, fall regularly a prey to the bald eagle, and they are stolen from unwary sportsmen just as readily as larger birds. Mr. C. J. Maynard mentions seeing an eagle swoop down and bear away a bufflehead (*Charitonetta albeola*) just shot and lying on the water only a few yards distant. Wounded ducks, with those purloined from hunters, form at some seasons a good share of its food. It has been seen to drop suddenly and unexpectedly to the water and catch a black duck (*Anas obscura*) before there was any chance of escape, but usually the duck sees the eagle as it comes, and then the process of capture is more protracted. The eagle rushes at its intended victim, which on its approach dives and swims under water until compelled to return to the surface for air, when the eagle again swoops down; and this procedure is repeated until the duck becomes exhausted, is seized, and carried away. Dr. S. D. Judd has seen a wounded scaup duck (*Fuligula marila*) tired out in this way, and saved only by a shot at the eagle. According to observers, such a chase is seldom voluntarily given up until successful. Sometimes two together pursue the duck, making alternate attacks, whereby the hunt is shortened. It is, however, quite capable of catching ducks on the wing, apparently experiencing little difficulty on account of their swift flight.

This eagle is fond also of coots (*Fulica americana*), and Dr. William L. Ralph, quoted by Major Charles E. Bendire, says that during winter in the vicinity of Merritt Island, Indian River, Florida, it feeds largely on the coots which then abound there, hunting them

* Abstracted from Bulletin 27 of Biological Survey of the Department of Agriculture.

† The birds from Alaska and much of British America are considerably larger than those from farther south, and on this account have been separated as a distinct race (*Haliaetus leucocephalus alascanus* Townsend).

* Forest and Stream, xviii., 1882, p. 85.

* Bulletin Nutt. Ornith. Club, v,. 1880, pp. 57-58.

usually on the wing. One eagle's nest with two well-grown young, visited by him, contained besides a catfish (*Ameiurus?*) the remains of thirteen coots. Still other water birds are not infrequently captured for food, and of these the various kinds of gulls probably most often. Mr. Everett Smith, writing in Forest and Stream,* describes an unsuccessful attack upon a loon (*Gavia immer*) in Maine, ostensibly for the fish it had apparently just caught, but possibly with a more sinister purpose; and Mr. W. W. Worthington gives an instance of the capture of a Florida cormorant (*Phalacrocorax auritus floridanus*) at Darien, Ga.†

The bald eagle preys to only a limited extent on the native gallinaceous birds, and then probably for the most part when other means of sustenance are scarce. In Alaska it lives somewhat on ptarmigan (*Lagopus*), particularly in winter, when ducks and geese are gone and fish comparatively hard to obtain. Mr. G. Elfrig records finding a young eagle fighting a wild turkey on Knobley Mountain near Cumberland, Md. Audubon says that the bald eagle used to frequent the roosts and breeding places of the passenger pigeon (*Ectopistes migratorius*) for the purpose of picking up the young birds that happened to fall from the nests or any old ones that chanced to be wounded, but that it seldom followed the migrating flocks of pigeons.

Domestic fowls, principally chickens and ducks, are sometimes killed, to which fact several writers testify. Mr. Charles F. Batchelder was informed that in northeastern Florida the eagle at times carried off poultry, even venturing near the houses for this purpose. Dr. S. D. Judd found a recently-killed Plymouth Rock hen in the nest of a pair of eagles near Marshall Hall, Md.; he also states that at the same place domestic ducks are occasionally taken. Yet this eagle does not seem to be a confirmed chicken stealer, and levies on poultry only when most accessible or when other supplies fail.

Mammals of many kinds constitute a considerable share of the food, but the larger quadrupeds are not often attacked. The four-footed animal, unless a large one, when struck by the eagle has little chance for escape, since one talon usually pins the two fore legs and head together, while the other pinions the hind feet, and the beak soon breaks the spine of the victim. If the animal be too large to be carried away, the eyes are the first point of attack.

At favorable opportunities this eagle preys upon fawns, and pressed by hunger will sometimes attack a full-grown deer, particularly if the latter be wounded. Remains of a mule deer (*Odocoileus canus*) were found by Dr. E. A. Mearns in the stomach of one from the Mogollon Mountains, Arizona. Mr. E. W. Nelson is authority for the statement that in northern Alaska it feeds at times on young reindeer (*Rangifer arcticus*). Even the wily fox sometimes meets its fate at the talons of this powerful bird, as is shown by Mr. Vernon Hailey's report that at Provo, Utah, a farmer found a gray fox (*Urocyon scotti*), evidently just killed, which a pair of eagles were busy eating. Opossums (*Didelphis*) and raccoons (*Procyon lotor*) are sometimes captured, but the nocturnal habits of these animals probably account for their not being more frequently obtained. Mr. Thomas McIlwraith mentions that an eagle shot at Hamilton Bay, Ontario, had the bleached skull of a weasel hanging firmly fastened by the teeth into the skin of its throat, a grewsome relic of a former desperate struggle.

Rodents of various kinds form an element of some importance in the diet of the bald eagle. Where squirrels (*Sciurus*) are plentiful they are freely eaten. In California, according to Dr. J. G. Cooper, large numbers of the destructive ground squirrels, or spermophiles (*Citellus*), were formerly killed on some of the ranches, the birds receiving protection in consequence; and instances were reported to him of young eagles reared from the nest and kept in a semi-domestic state, which went out daily to kill squirrels—a hint, perhaps, for California wheat raisers. Prairie dogs (*Cynomys ludovicianus*) are eaten occasionally, but not so commonly as doubtless they would be were this eagle more numerous in the regions where these destructive rodents most abound. Mr. William Lloyd reports visiting a bald eagle's nest containing young, to which the adult birds were seen to bring two prairie dogs; and skins of this mammal were found among the debris of the nest. Rabbits are frequently taken for food; rats and even mice occasionally.

Unfortunately the bald eagle's fondness for mammal flesh leads it to attack domestic animals. This happens rarely to the larger kinds, though a sickly or weakling calf may once in a while be killed; but sheep and hogs in some places suffer considerably. Full-grown healthy sheep are seldom killed, the attacks being confined principally to sick and weakly animals and to lambs. Alexander Wilson quotes at some length from Mr. John L. Gardiner, who a hundred years ago lived near the eastern end of Long Island, New York, showing that this eagle at that early day had already acquired a fondness for mutton. Mr. Amos W. Butler mentions‡ an eagle taken in Knox County, Ind., in October, 1896, that had killed two lambs. Mr. A. F. Gray records§ an instance at North Coventry, Chester County, Pa., of an eagle that carried off a large lamb and returned the following day for another; and Mr. J. Otis Fellows tells‖ of an eagle that at Hornellsville, N. Y., in the spring of 1878 swooped down on a flock of sheep, and, as he expressed it, "made a breakfast on lamb chops before he could be driven off." Mr. H. W. Henshaw, writing of the northern Pacific coast region of the United States, says that many lambs were annually destroyed by the bald eagle.

Many writers note the destruction of swine by the bald eagle, but these reports almost all refer to young animals. In places, particularly the southeastern United States, where this eagle is common, and where large numbers of pigs are raised and allowed to run more or less wild, there is from this source a loss that at times is by no means insignificant, the bird occasionally venturing boldly even close to human dwellings in pursuit of its prey. Wilson records that in the lower parts of Virginia and North Carolina in his time it destroyed great numbers of young pigs, and that complaints there against the birds were very general. A writer in Forest and Stream* states that a bald eagle was killed by a Mr. Towry near Smithville, Miss., as it was feeding on one of two hogs that it had just killed; and Mr. C. J. Maynard says that in Florida he once saw three eagles attacking several young pigs which were, however, valiantly defended by their mother.

Mr. Vernon Bailey reports that on one occasion the little dog of a ranchman in the Davis Mountains, Texas, was picked up by a bald eagle, but finally dropped. Dogs are, however, sometimes eaten.

The bald eagle does not disdain carrion, and in some parts of the arid West it lives at times to a considerable extent on the cattle and smaller domestic animals that fall victims to drought or other catastrophe. Several of the early ornithological writers, including Wilson, mention its abundance along the river below Niagara Falls, whither it used to resort for fish and for the carcasses of the various animals that had been precipitated over the falls. Wilson tells also that on one occasion when many thousands of tree squirrels were drowned in attempting to cross the Ohio River not far from Wheeling, W. Va., and a great number drifted to the shore, a bald eagle for several successive days regaled itself on them. Carrion was found in the stomachs of two eagles examined by Dr. A. K. Fisher; Mr. Horace A. Kline has seen this bird along the Wakulla River in Florida feeding on the carcass of an ox, again on that of a sheep; and Mr. L. M. Turner, while visiting Atkha Island in the Aleutian chain, Alaska, found a pair wrangling with gulls and ravens over the decaying remains of a sea-lion. Sometimes it drives away the gathered vultures or the dogs from their repast and keeps them at a respectful distance until its hunger is satisfied. Furthermore, it does not hesitate even to pursue the vultures and compel them to disgorge, when if it fail to catch the coveted morsels before they reach the ground it alights and devours them. Audubon relates that on one occasion he saw it kill a vulture that for some reason was unable completely to disgorge.

Along the shore of the Bay of Fundy, in May, 1833, Audubon found this eagle in company with crows and ravens feeding on mussels and "sea eggs." Occasionally it seizes prey that it is unable to eat, as in the following case mentioned by Major C. E. Bendire on the authority of Mr. Samuel B. Ladd: The ground beneath a nest found by the latter gentleman in Lancaster County, Pa., was strewn with land terrapins in various stages of decay, which the eagles had evidently taken to feed their young and upon more careful examination thrown out of the nest.

* Vol. iii., 1875, p. 324.

† Bendire, Life Histories of North American Birds [i.]. 1892. p. 279.

‡ Twenty-second Ann. Rep. Dep. Geol. and Nat. Res. Indiana, 1897 (1898). p. 794.

§ Forest and Stream, v., 1876, p. 195.

‖ Ibid., x., 1878, p. 319.

The use of low temperatures enabled V. Thomas and P. Dupuis, of Paris, to make some researches showing the chemical affinity of liquid chlorine. Iodine when placed in contact with liquid chlorine is rapidly attacked, and there results a brown mass which is changed to a yellow powder in an excess of chlorine. This body is the trichloride of iodine, which is insoluble or nearly so in an excess of liquid chlorine. The process is the best one for preparing this body in the laboratory in a pure state. As the chloride of iodine has a very strong action on the hydrocarbons, some compounds can be produced, such as C_6Cl_6 containing a large amount of chlorine. By reacting upon some of the iodides, such as those of lead, liquid chlorine also gives chloride of iodine and a metallic chloride. Bromine gives a reaction like that of iodine upon liquid chlorine, and we obtain a proto-bromide of chlorine, BrCl, which will take on chlorine to form the trichloride $BrCl_3$. A perchloride is also formed, and this body is a red mass which is solid at about —75 deg. C. Somewhat above this it melts to a light orange liquid which boils at —19 deg. and gives off a greenish vapor which is darker than chlorine gas. While still below zero degrees it decomposes, and the liquid residue is the protochloride of bromine. By heating this strongly and then cooling, we solidify it to a dark red mass at —39 deg. C. Experiments with the action of liquid chlorine upon sulphur, selenium, etc., show that while the action of sulphur is slow, selenium and tellurium give a good reaction. These bodies furnish compounds of the type MCl_2 and then MCl_4. When a mixture of chlorine and sulphurous gases is sent through a tube kept at a low temperature, the two gases are found to condense into a homogeneous liquid. When the temperature rises, the liquid is not all volatilized, and at the ordinary temperature there remains a dense liquid, which is the chloride of sulphuryl SO_2Cl_2. It is decomposed by water. This reaction is interesting, as it is not carried out at the usual temperatures. Arsenic reacts with liquid chlorine at the boiling point of the latter with a very strong effect accompanied by incandescence, and we obtain white fumes of trichloride of arsenic. Other bodies such as antimony, bismuth, and gold, give but slow effects. Gold forms a trichloride after a long time. It is curious to note that while chlorine gas has a strong reaction on bisulphide of carbon, we find that liquid chlorine at a low temperature has no reaction on this body, but seems to mix with it in all proportions.

* "G. C. E.," Forest and Stream, viii., 1877, p. 17.

ENGINEERING NOTES.

A correspondent of the London Engineer gives the results of experiments on the comparative strength of cast-iron test bars. In the case of bars from metal run quite hot into the mold and of bars cast from metal kept in the ladle until so cold that it would just run and fill the mold, there was no appreciable difference in ultimate strength between the hot and dull run bars, but the dull run bar was much stiffer. In regard to the action of blows, a cast-iron tensile link, whose neighbors all stood from 12 to 13 tons per square inch, broke with a load of 7 tons, after a number of smart taps with an iron pin upon the link while bearing the 7-ton dead load. At each tap given to the link the pointer registering the extension visibly dropped until fracture took place.

Astonishing evidence of the adaptability of the conservative lake interests to new conditions is given in the publication by the Marine Review of a list of the vessels of 500 feet length or more ordered since the "Wolvin" went out with her first cargo in 1904. No less than seventy-seven such boats are enumerated, and their carrying capacity in an ordinary season would be close to 15,000,000 tons. Reckoning an average cargo of 9,000 tons of ore for these boats—some of them will carry 10,000 to 12,000 tons, the average length over all being close to 540 feet—they represent from two and a half to three times the capacity of a like number of boats of the average capacity obtaining ten years ago. The revolution is even greater than that which has been considered so phenomenal in the case of the modern railroad car.

Tests on water-tube feed-water heaters are stated to have shown that when the water was pumped through the heater at such a rate that the final temperature was within 15 deg. of the temperature of the steam, the transmission per square foot of tube surface was about twice as great as when the water was pumped through so slowly that its final temperature was within 5 deg. of the temperature of the steam. This shows that when a closed heater of this type is forced the efficiency of the heating surface is greatly increased, due to the more rapid rate at which the water is forced through the pipes, and to the greater difference between the temperature of the steam and the average temperature of the water. Steam-tube heaters have a relatively small overload capacity on account of the sluggish circulation of water between the pipes and the shell. Closed heaters generally contain from one-third to one-half square foot of heating surface per horse-power, which, on the basis of raising 30 pounds of water per hour from, say, 50 to 200 degs., is equal to a heat transmission of from $30 \times (200 - 50) = 4{,}500$ heat units to one-third or one-half square foot, or 13,500 or 9,000 heat units per square foot respectively. As such surface becomes fouled by the accumulation of scale or sediment on one side and cylinder oil on the other, the efficiency of the heater rapidly decreases.

The chemical composition of producer gases varies considerably according to the kind of fuel used and the manner in which the gas is generated. In the true sense of the term, producer gas is made in special generators working either under pressure or by suction. Mond gas has perhaps been manufactured on a larger scale than any other gas except coal gas, and Mond gas is produced from bituminous coal in producers of the pressure type. It is essential with Mond gas that purifiers should be used, and it is possible to collect the by-products. It is therefore advanced by many engineers that Mond gas plants are complicated, and it is generally recognized that such plants are only economical when worked with large gas engines, when it pays to recover the by-product from the gas. Water-gas should be composed of about equal parts of carbon monoxide and hydrogen, and is obtained by the decomposition of steam by means of incandescent coal. As a matter of fact, the gas also contains a small proportion of nitrogen and carbon dioxide. The gas has been used considerably of late to mix with ordinary coal gas, and the result has been that the prices of coal gas have been lowered in consequence of the addition of water gas with it. The method of making the gas is comparatively simple, and the principle is that air and steam are blown alternately into a generator, the first in order to fan the fire, and the second to produce the gas. It may be mentioned that on account of the carbon monoxide it is very poisonous and consequently dangerous to human life, and an objection to it is that the gas is generated under pressure. At the same time there is in its favor the fact of the high temperature of the flame. Gas has been obtained from wood in an apparatus invented by one Riché, and this gas is also rich in carbon monoxide, containing some twenty-nine per cent of it. There is also a large percentage—to be accurate, about forty-four per cent—of hydrogen, although there is very little nitrogen. The principle upon which the Riché apparatus works is that there is a retort which is charged with wood for fuel. There is an obvious advantage for such apparatus in sawmills and other factories where

wood is a waste product, but, of course, here again we are met with the dangerous constituent carbon monoxide.

TRADE NOTES AND FORMULÆ.

Pliant Shellac Varnish.—Add 5 parts Venice turpentine and from 20 to 30 parts oil of spike to 100 parts shellac varnish. Any desired color can be imparted to the varnish by adding concentrated solutions of suitable coal-tar dyes.

Fireproof Paper.—Steep 95 parts of asbestos fiber in a solution of calcium permanganate; treat with sulphuric acid and mix with 5 parts of ground wood pulp. Add size and borax, put the whole in a paper mill, and complete the process as with ordinary paper.

Liquid Glue.—An adhesive liquid glue can be made according to the following recipe: Dissolve 40 parts white gelatine in 40 parts acetic acid in a water bath; add 10 parts spirits of wine and 2 parts alum for its better preservation.

Iron Varnish for Smiths, Locksmiths, and Iron Founders.—Heat 200 parts by weight of pine-oil and dissolve in it 25 parts of Syrian asphalt and 25 parts of rosin, previously crushed a little. When cool, pour the varnish into a bottle and keep. When heating the pine-oil, be careful that the vapors do not come into contact with the fire or the oil will ignite.

Grease for Horses' Hoofs.—The two following recipes for making grease for horses' hoofs are given by Twisselmann in the Pharmazeutische Zeitung (Berlin):

Horse grease, 5,000 parts; tallow, ordinary quality, 2,000 parts; train oil, 3,000 to 5,000 parts; oleic acid, 1,000 to 1,200 parts; lampblack, sufficient for coloring; nitro-benzol 100 parts.

Isinglass Cement for Metal.—This consists of 100 parts isinglass solution and 1 part nitric acid. Stir the nitric acid evenly in a very thick isinglass solution and paint the metallic surfaces with this liquid. The surfaces must be firmly pressed together. The object of the nitric acid is to make the surfaces rough by corrosion; its use, however, is attended with this disadvantage, that it hinders the drying of the cement. It is therefore necessary to expose the cemented metallic surfaces to a higher temperature for a time to hasten the drying.

Packing of Bottles Containing Solutions.—For packing bottles containing solutions, especially solutions used in photography, so as to protect them from being broken, A. E. Towers (Wiener Photographische Mitteilungen) recommends the employment of pneumatic bicycle tires which have become useless for any other purpose. Rings from 1½ to 2 inches in height are cut from these burst tires and either put round the upper and lower ends of the bottles (thus avoiding all danger of breakage in the event of the bottles knocking against each other) or pulled over the whole bottle. These tires can be procured very cheaply and dealers will find that bottles protected in this way will be greatly appreciated by their customers, who will be glad to pay a reasonable charge for them. Pieces of old pneumatic tires are also well adapted for cylindrical tin cans in which platinum paper is kept. They are pulled over the junction of the lid and cylinder, rendering the can entirely airtight.

Protective Coating for Metals.—Grind 1,000 parts, by weight, of lead as fine as possible in a wet mill with water, and as soon as a deposit has formed, throw away the water and mix the deposit with a platinum precipitate. The latter is obtained in the following manner: Add 25 parts of ammonia to a solution of 12 parts crystallized platinic chloride in 1,000 parts of water; allow to stand for 3 hours till a deposit has formed, decant the ammonia water, substitute pure water for it, again allow to settle for three hours and decant the water. Grind the platinum for at least half an hour with the borate of lead and add 5,000 parts of water; the mass will then be ready for use. The iron, steel, or copper articles which it is desired to coat must be well brushed or washed, plunged into the preparation or coated with the latter by means of a brush, and heated in a very hot muffle or in a gas flame till the originally white coating has taken on the color of dull iron.

Bronze Varnish for Iron.—Add 112 parts, by weight, of shellac and 14 parts benzol to 500 parts methyl alcohol, put the bottle in a warm place and shake the mixture frequently. When the shellac is dissolved, leave the bottle in a cool place for two or three days till the solution is clear, pour the clear fluid into another bottle, and well cork the latter in order that the contents may be fit for use on the most delicate work. Add sufficient spirits of wine to the sediment remaining in the first bottle for the mass to be easily taken up with a brush, and pour the mixture through a thin cloth. This mixture may be used as a priming and for coarse articles. If it is desired to make a paint, mix as much green bronze powder as necessary with the proper quantity of the second fluid. To alter the shade, a little lamp-black may be mixed in for dark colors, red and yellow ocher for brighter colors. The iron which it is desired to paint must be clean and smooth and the paint applied thin and with a soft brush. When the first coating is dry, a second is added and the application renewed till a nice, uniform bronze surface has been obtained. The portions in relief should be painted very gently with the free varnish and gold bronze applied; when completely dry, spread a thin layer of varnish once more over the whole.

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